PB84-151349

Removal of Organic Contaminants from the Drinking Water Supply at Glen Cove, New York

Nebolsine Kohlmann Ruggiero Engineers, New York

Prepared for

Municipal Environmental Research Lab.

Jan 84

U.S. Department of Commerce
National Technical Information Service
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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-84-029	2.	3. RECIPIENT'S ACCESSION NO. PB84 151349
4. TITLE AND SUBTITLE Removal of Organic Contaminants from the Drinking Water Supply at Glen Cove, NY		5. REPORT DATE January 1984 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Dominick D. Ruggiero		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Nebolsine Kohlmann Ruggiero Engineers, P.C. 1250 Broadway New York, NY 10001		10. PROGRAM ELEMENT NO. BNC1A 11. CONTRACT/GRANT NO. CR806355
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cinti, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Project Report 3/28/79-1/28/83 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Walter A. Feige Tel. 513-684-7496

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 339
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-600/2-84-0
January 1984

PB84-15134

REMOVAL OF ORGANIC CONTAMINANTS FROM THE DRINKING WATER SUPPLY AT GLEN COVE, N.Y.

FINAL REPORT

by

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, four water and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communication link between the researcher and the user community.

The results of a pilot plant study to remove organic contaminants from ground water are reported here. This study features the examination of synthetic resin adsorption with in-place steam regeneration and aeration techniques and includes the computation of cost analyses for each approach tested. The desired target level is shown to be an important consideration in the interpretation of the data and in the choice of treatment technique.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

This research program was performed with the overall objectives of obtaining relevant design parameters and capital and operating costs of both adsorption and various aeration techniques for the removal of specific organic contaminants from the City of Glen Cove's drinking water supply. Major contaminants present were trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene and 1,1,1-trichloroethane.

A pilot plant was constructed and operated for three phases by using water from one of the City's contaminated wells as the influent to several treatment units. The four year pilot plant testing program was completed January 28, 1983. During this period the pilot plant studies evaluated the removal of the contaminants by adsorption using a synthetic resin (Ambersorb® XE-340) and several aeration methods including diffused aeration, packed column induced air spray aeration, and air-lift pumping. During the third phase, the U. S. EPA delivered, installed and operated a packed column air-stripping system utilizing induced air.

The adsorption system using virgin or freshly regenerated resin proved to be able to remove all contaminants of concern to below 1 ug/L. The best approach to resin testing proved to be downward operation with countercurrent regeneration. Steam regeneration of the exhausted resin appears feasible but additional research is needed on proper condensate handling and disposal methods. Aeration proved successful as a method for volatile organic contaminant removal. Most of the aeration units tested reduced contaminants to levels that met present New York State guidelines and to levels that might be universally acceptable. Further development is required for the air-lift pumping system before it can be considered as a feasible treatment alternate.

This report was submitted in fulfillment of Cooperative Agreement No. 806355 by Nebolsine Kohlmann Ruggiero Engineers, P.C. for the City of Glen Cove, N.Y. under the partial sponsorship of the U.S. Environmental Protection Agency. This report contains the final report for the entire project period, March 28, 1979 through January 28, 1983 and also contains the Phase III report which covers the period from October 14, 1981 to January 28, 1983.

ACKNOWLEDGEMENTS

The authors particularly wish to thank Mr. Brad Smith of the M.E.R.L., Cincinnati, for his aid in all analytical phases of this work, Mr. Kim Fox for his help with particulate analyses, Mr. Walter A. Feige and Dr. O. Thomas Love, Jr., for providing extremely valuable guidance during the test work and in the preparation of this report, and Mr. Michael Cummins for providing his aeration column for evaluation.

Mr. Eric Isacoff of Rohm and Haas Company was always available for advice about the resin. He also helped in conducting the regeneration attempts, and facilitated the transfer of information necessary in such projects.

We would also like to thank the Mayors of the City of Glen Cove during this research project period, Honorable Vincent A. Suozzi and Honorable Alan M. Parente, Mr. Joseph Hurley, Director of Public Works for the City of Glen Cove, Mr. Frank Macedonio, Controller for the City of Glen Cove, and the Glen Cove Water Department, in particular, Mr. Anthony Caruso and Mrs. Margaret d'Esposito, as well as the men stationed at the test site.

Similarly, we appreciate the assistance of the Hydrotechnic Corporation staff, in particular, Ivan Pouschine, Jr., with all phases of this project.

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SECTION 1

INTRODUCTION

The City of Glen Cove, New York, located on the north shore of Long Island, receives its drinking water supply from a series of wells located throughout the City. Even though Long Island is part of New York State and parallels the southern coast of New England it is separated from the mainland by a salt water body, Long Island Sound. The drinking water supply on Long Island is from aquifers classified sole source water supply since the water supplies to most communities do not have easy access to the water sheds on the mainland. Communities such as the City of Glen Cove, which depend on underground aquifers as the sole source of their water supplies, are greatly affected by contamination of these underground water supplies.

In 1977 the Glen Cove water supply system consisted of nine (9) wells designated as Duck Pond Rd. Wells Nos. 1 and 2, Seaman Rd. Wells Nos. 1 and 2, Morgan Island Well, Roxbury Well and Carney Street Wells Nos. 20, 21, and 22. These wells were capable of delivering more than an ample supply of water to meet requirements, which was a normal demand of approximately 3 million gallons per day (11, 355 m3/day) and 8 million gallons per day (30, 280 m3/day) during peak summer months. Analyses performed in the summer of 1977 by the Nassau County Department of Health, indicated that the water from Seaman Rd. Well No. 1 and Carney Street Wells Nos. 20, 21, and 22 contained concentrations of trichloroethylene and tetrachloroethylene above the New York State's maximum guidelines limits of 50 micrograms per liter (ug/L) for any one organic contaminant and a total allowable limit of 100 ug/L for all such compounds. The use of these wells was restricted by the County Health Department.

This reduction in the water supply caused the City of Glen Cove to begin an evaluation of methods to augment their reduced supply and the City arranged to purchase water from adjoining communities until an adequate supply could be reestablished. In an effort to regain a sufficient water supply the City decided on two approaches: the drilling of new wells in a non-contaminated area, and the determination of a treatment system which would render the water in contaminated wells usable.

The consulting engineering firm of Nebolsine Kohlmann Ruggiero Engineers, P.C. (NKRE) was retained by the City of Glen Cove for the determination of a feasible and economical treatment system. Through consultation with the U.S. Environmental Protection Agency's (EPA) Drinking Water Research Division, Municipal Environmental Research Laboratory (MERL), Cincinnati, Ohio, it was determined that no treatment system existed at the time capable of treating large volumes of water containing these organic contaminants. After some preliminary testing of the Carney St. wells,(1) discussions and negotiations between the City of Glen Cove, NKRE and the U.S. EPA resulted in a research grant (later a cooperative agreement) funded by the U.S. EPA in 1978 to test several possible treatment methods at the Glen Cove site.

The pilot plant testing program actually covered three phases of operation over a four-year period beginning March 28, 1979, and completed January 28, 1983.

Phase I

The first phase was approved in October 1978 and the actual pilot plant testing was conducted from March 28, 1979 to January 3, 1980. The main objectives of this study were as follows:

1) Aeration Studies

   Evaluate the use of diffused aeration as a method to remove volatile organic compounds from a drinking water supply to determine the most efficient air to water ratio and to evaluate the effect of the off gases on the ambient air.

2) Adsorption Studies

   Evaluate the use of synthetic resin as a method of removing these particular volatile organics from a drinking water supply. This evaluation included a determination of proper resin bed depth, the regenerability of the resin on-site with steam and the method of handling the condensate produced during regeneration.

The results of the Phase I testing are presented in report number EPA-600/2-80-198 titled "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase I,(2) and a summary of this report appears in Appendix A. The results from this phase warranted extending the test program to continue development of the technologies.

Phase II

The U.S. EPA's Drinking Water Research Division approved the Phase II extension of the study in March 1980. The pilot plant operations for Phase II were conducted from May 27, 1980 to January 30, 1981. The main objectives of this second phase were as follows:

1) Aeration Studies

   Continue the diffused aeration testing and install and evaluate, for comparative purposes, a packed column aeration system and a small cooling tower.

2) Adsorption Studies

   - Evaluate the resin system in both upflow and downflow modes of operation.
   - Improve the steam regeneration system to eliminate steam condensation and losses by applying steam concurrently and countercurrently to flow. Investigate higher steam loadings.
   - Determine the feasibility of regenerating granular activated carbon with steam.
   - Evaluate the resin system for its corrosive properties and the correct materials for construction.

The results of this second phase of the project are presented in report number EPA-600/2-82-027 titled "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y.: Phase II"(3) (Project Summary EPA-600/S2-82-027). A summary of this report appears in Appendix B. The results of the testing during Phase II warranted extending the test program for a third period.

Phase III

The U.S. EPA's Drinking Water Research Division approved the Phase III extension of the study in July of 1981, and the actual pilot plant operation was conducted from October 14, 1981 to January 28, 1983. The major objectives of this third phase were as follows:

1) Aeration Studies

   - Continue the diffused aeration testing as a pretreatment step to resin adsorption utilizing the same column except that the top of the column would be covered and air flow directed through a duct for ease of sampling.

- Evaluate a spray aeration column utilizing induced air.
- Evaluate the use of an air-lift pump as a method of air-stripping the volatile organics.
- Evaluate the effect of the off-gases on ambient air.

2) Adsorption Studies

- Evaluate the maximum hydraulic loading for the resin system.
- Continue the development of the steam regeneration technique.
- Evaluate the effect of multi-regenerations
- Determine the wave front of each particular volatile organic as it moves through a four (4) foot granular activated carbon bed.

3) Combined Aeration-Adsorption Studies

Evaluate the use of aeration followed by resin as a combined technology approach to treatment.

The results of this third phase of the project are presented in a report contained in Appendix C of this report titled "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase III."

The results of the overall study are summarized in this final report.

SECTION 2

CONCLUSIONS

The conclusions presented below are the overall conclusions from the three phases of the project. Conclusions from each phase appear in Appendices A, B and C.

AERATION STUDIES

A. General

The following conclusions are applicable to all aeration methods tested during the three phases except as noted under the particular unit process.

1. Aeration as a technique for the treatment of volatile organics present in ground water will reduce cis-1,2-dichloroethylene, trichloroethylene, tetrachloroethylene and 1,1,1-trichloroethane, to levels which will meet present New York State guidelines and to levels which might be universally acceptable.

2. Most of the systems evaluated can be detailed designed and a full-scale plant installed. Some of the systems will require additional testing to determine the most economical design parameters.

3. There is no apparent effect on the ambient environment. Air discharging the units contains levels of contaminants below any existing air standards and the concentrations may not be measurable after mixing with the ambient air. The aeration units do not produce any liquid or solid wastes which must be disposed and, therefore, will have no impact on any ambient conditions.

4. There is no apparent effect on the final water quality particulate levels contributed by ambient air quality for systems using induced ambient air. This is based on the ambient air conditions at the Glen Cove, N.Y., site and should be confirmed at other sites, especially in areas where air pollution is prevalent.

5. The estimated capital costs for full-size plants are based on plant capacities of 1 to 5 mgd (3,785-18,925 m3/day). The estimated annual operating costs presented in the conclusions section include amortization and are based on an electrical cost of $0.09 per kWh. All estimates are based on costs for February 1983.

B. Diffused Aeration Studies

1. To achieve desirable water quality the diffused aeration system must operate at an air to water ratio of 15:1 or higher. Using this air to water ratio the system will remove between 60-95 percent of all compounds tested with an average overall removal of about 84 percent.

2. The removal efficiency can be increased by adding a second stage diffused aeration unit or possibly by increasing the height of the diffused aeration unit.

3. The estimated capital costs of a full-scale diffused aeration system range from $270,000 to $563,000, and the estimated annual operating costs range from $0.20 to $0.37 per 1000 gallons (3.79 m3) of treated water.

C. Packed Column Diffused Aeration Studies

1. In general, the conclusions discussed under diffused aeration studies also apply to the packed column aeration studies, with the following additions or exceptions.

2. The use of packing material produced a slight improvement over that of diffused aeration achieving an overall removal of contaminants of about 83 percent using air to water ratios of 10:1. The system must be operated with the packing above the operating water level to achieve these results.

3. The estimated capital cost for the full-scale operating system ranges from $341,100 to $846,500 and the estimated annual operating cost ranges from $0.19 to $0.37 per 1000 gallons (3.79 m3) of treated water.

D. Induced Air Spray Aeration Studies

1. The testing in Phase III concluded that this approach required packing in the unit to provide enough air to water contact time to achieve acceptable levels. Using at least 4 ft (0.12 m) of Munters Corporation packing

the overall reduction of organic contamination was better than 90 percent.

2. The estimated capital costs for a full-scale induced air spray aeration plant utilizing packing range from $231,000 to $629,500 and the estimated annual operating costs range from $0.10 to $0.23 per 1000 gallons (3.79 m3) of treated water.

E. Packed Column Air-Stripping Evaluation

1. The test column used for this evaluation was designed and delivered to the site by U.S. EPA personnel who installed it and operated it during the two test periods. This unit used plastic saddles, purchased from Glitsch, Inc., and had the highest overall removal efficiency, exceeding 95 percent, of all aeration or air-stripping methods evaluated.

2. The estimated capital costs for full-scale packed column air-stripping plants range from $185,500 to $439,000 and the estimated annual operating costs range from $0.09 to $0.21 per 1000 gallons (3.79 m3) of treated water. These are the lowest estimated capital and annual operating costs of all systems evaluated during this research project.

F. Air-lift Pumping Studies

1. The operation at the Glen Cove site was not under optimum conditions because the air to water ratios used were greater than those required to deliver the desired water quality.

2. The system exhibited relatively poor efficiency (~ 50%) in removing the volatile organics. This approach requires additional evaluation before it can be considered for full-scale operation.

3. The estimated capital costs for an air-lift pumping installation range from $274,000 to $730,000 and the estimated operating costs range from $0.24 to $0.42 per 1000 gallons (3.79 m3) of treated water. This operating cost is the highest cost of the systems evaluated during the research program.

G. Induced Draft Cooling Tower Studies

The unit used to evaluate this method was a small demonstration model supplied by Baltimore Air Coil. It was difficult to control the air to water ratio and the unit had a rather low removal efficiency, between 48 and 61 percent. The water quality produced did not meet present New York State Guidelines and the unit is not considered ready for full-scale operation. Much additional testing is required before this

ADSORPTION STUDIES

A. Resin Adsorption Studies

1. The resin used for testing during this research project, Rohm and Haas' Ambersorb® XE-340 is not presently produced commercially. Under virgin or freshly regenerated resin conditions it is possible to remove all contaminants tested to non-measurable levels.

2. The breakthrough order for the contaminants, which has been apparent in all phases, is cis-1,2-dichloroethylene, trichloroethylene and then tetrachloroethylene.

3. Ambersorb XE-340 is steam regenerable, requiring steam equivalent to 20 to 30 bed volumes of steam condensate applied at a flow rate of one bed volume per hour. However, the proper handling of the condensate produced during steam regeneration must be further developed. The principle of "superloading" appears to be a feasible approach.

4. The best mode of operation proved to be countercurrent, with downward flow application and upward steam regeneration.

5. Particle size distribution of the resin is of extreme importance for removal of volatile organics by XE-340.

6. The optimum hydraulic loading for the resin appears to be an application rate of 4 gpm/ft3 (0.42 Lpm/m3) producing an empty bed contact time of 1.9 minutes, when considering the overall removal of the contaminants involved during this research program. The actual optimum hydraulic load for the removal of a particular contaminant should be determined by considering the service time and economics for various hydraulic loadings to achieve a desirable water quality.

7. The estimated capital costs for a full-scale plant having the same capacities as for the aeration units and based on an application rate of 4 gpm/ft3

0.42 Lpm/m3) range from $432,000 to $1,446,000 which is the highest estimated capital cost for all methods evaluated during this research program. The total estimated annual operating costs, including regeneration and the cost of hauling the condensate to an approved site for disposal, ranges from $0.18 to $0.32 per 1000 gallons (3,785 liters) of treated water.

B. Granular Activated Carbon Studies

The purpose of these studies was not to evaluate the adsorptive abilities of granular activated carbon but rather to evaluate the feasibility of regenerating activated carbon with steam and determining the movement of contaminants through a granular activated carbon bed.

1. The results of the regeneration attempts showed that the regeneration of granular activated carbon with steam, utilizing the steam equipment and conditions designed to regenerate resin, was not successful.
2. The studies to determine the movement of contaminants through a granular activated carbon bed indicate that cis-1,2-dichloroethylene penetrated at the fastest rate, followed by trichloroethylene and tetrachloroethylene in that order. The slowest penetration rate was exhibited by 1,1,1-trichloroethane.

COMBINED AERATION-RESIN STUDIES

The combination studies using diffused aeration as a pretreatment unit process to resin adsorption indicated that the time between regenerations was increased and that the frequency of regeneration could be reduced to about one-fifth (1/5) of that required without pretreatment. It appears that 4 gpm/ft3 (0.42 Lpm/m3) would be the optimum application rate with or without pretreatment when considering the overall removal of all contaminants studied. As for direct resin systems the optimum hydraulic loading for the removal of a particular contaminant must be determined by evaluating the service time and economics of applicable hydraulic loadings to achieve a desirable water quality. The cost of this combination based on an application rate of 4 gpm/ft3 (0.42 Lpm/m3) would be the sum of the cost of the aeration method used and the cost of a total resin system. The only cost savings would be a small amount due to the lesser regeneration frequency required. The estimated capital cost for plants having capacities from 1 to 5 mgd (3,785-18,925 m3/hr) range from $617,000 to $2,176,500 and the total annual operating cost based on an electrical cost of $0.09 per kWh ranges from

$0.25 to $0.73 per 1000 gallons (3.75 m3) of treated water. These high capital and operating costs make the combined approach unattractive and the system should only be considered when extremely high water qualities must be guaranteed.

SECTION 3

RECOMMENDATIONS

For some systems evaluated during this research project, design parameters have been sufficiently established to allow for the design and installation of a full-scale unit while others require additional testing to determine the optimum and most economical design parameters. Some of the systems evaluated do not appear to be feasible and additional testing is not warranted. The following are recommendations to further develop the treatment system to remove organic contamination from a gound water supply which should be considered for other research projects:

1. A full-scale demonstration plant should be installed to evaluate air-stripping of contaminants on a continuous basis.
2. Additional testing should be performed to evaluate the economics and optimum conditions for several types of packing material, including the proper hydraulic loading and air to water ratio for each type of packing.
3. The effect of ambient air conditions on systems utilizing induced ambient air should be further evaluated and expanded to include potential contaminants other than suspended matter, e.g., bacteria and viruses. The testing should be conducted in a potentially high air pollution area.
4. Further development of steam regeneration procedures, in particular the proper handling and disposal of the condensate, needs to be made.
5. The optimization of steam regeneration techniques for granular activated carbon should be investigated.

SECTION 4

PILOT PLANT FACILITIES

The testing location for all phases was the Carney Street site, where the highest well water contaminant concentrations were found. Well 22 was utilized as the main water supply to the test units in all three phases. This well draws water from an aquifer about 160 feet (49 m) below ground level and has a pumping capacity of about two mgd (7,570 m3/day). In general, the pilot plant equipment for each phase was similar with certain special equipment added to complete the objectives of that phase.

The equipment for Phase I, which is shown schematically and in photographs in Appendix A, consisted of four 6-feet (1.83 m) high, 4-inch (0.1 m) diameter pyrex glass columns containing resins, a 30-inch (0.76 m) diameter plexiglass column for the diffused aeration testing, a blower to supply air to the diffused aeration column, an electric steam generator to supply steam for the resin regeneration and a complete gas chromatograph system to perform the required on-site testing. This equipment is described in detail in Appendix A.

Based on the results of Phase I, various changes and modifications to the pilot plant equipment were made before Phase II began. The system for Phase II is explained in detail in Appendix B. Also contained in this appendix is a schematic diagram and photographs of the equipment for Phase II. The major modifications were a change of the size of the resin columns, reduced to 2.2 feet (0.67 m) in height, a larger steam generator, insulation and electric heating of steam piping and columns during regeneration periods and the installation of a packed diffused column and a small cooling tower for air stripping evaluation. In addition, two of the 6-feet (1.83 m) pyrex glass columns were installed to test the feasibility of regenerating granular activated carbon with steam.

From the results of Phase I and II, major additions and modifications to pilot plant equipment were made before Phase III began. The modifications and additions included conversion of one of the aeration columns to evaluate spray aeration utilizing induced air, the purchase of a fan to be utilized with this column, the installation of an air-lift pump, the addition of a new blower and several columns, and the modification of a 6-foot (1.83 m) pyrex glass column to allow sampling at one-foot intervals through a granular activated carbon bed. These additions and modifications required a change in the basic layout of the pilot plant facilities. The blowers and aeration columns were moved away from the building so that the continuous operation of the diffused aeration system would not disturb the building's inhabitants. The blowers were placed in a shed on a concrete slab installed to support the blowers and aeration columns.

The air-lift pump was installed in Well No. 20 so that Well No. 22 could be utilized as the supply to the other testing systems. The testing system for Phase III is explained in detail in the Phase III report presented in Appendix C.

SECTION 5

TESTING PROGRAM AND OPERATION

The objectives of the testing program for all three phases were basically the same: the evaluation of resin adsorption and aeration methods for the removal of trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene and 1,1,1-trichloroethane from a drinking water supply. The pilot plant evaluated various aeration methods at various air to water ratios. This included diffused aeration, packed column diffused aeration, induced air spray aeration (with and without packing), air-lift pumping and a packed column air-stripping system supplied by the U.S. EPA.

The resin used was Rohm and Haas Ambersorb ® XE-340, designed to remove relatively non-polar organic molecules and halogenated aliphatics from water. Virgin resin was first hydrated before use. Were the resin not hydrated, its surfaces would repel water, resulting in less efficient adsorption. Since resin regeneration would be required in an actual operating plant, the pilot plant program attempted to determine an appropriate method of regeneration.

Influent and effluent samples were taken at appropriate times during each phase and analyzed on-site using the gas chromatograph (G.C.) purchased for this project. The G.C. system includes a Tracor gas chromatograph equipped with a halogen-specific, electrical conductivity detector, a Tekmar purge-and-trap concentrator and an automatic integrator. The frequency of sampling varied for each testing method and for each phase. All analyses followed the proper analytical procedure and quality control which is described in Appendix D.

The testing program and operation for each phase are detailed in the respective phase report. The following is a summary of the procedure.

The resin testing in Phase I was carried out in four pyrex glass columns each 6 feet high (1.83 m) and 4 inches (0.10 m) in diameter. The flow through each column was 21 gallons/hr (0.08 m3/hr), or an application rate of 4 gpm/ft3 (0.42 Lpm/m3), in a downward direction, and the system was designed to apply the regeneration steam in either an upward or downward direction. To evaluate the proper bed depth, resin was installed in Columns I, II and III at a depth of one foot, two feet and four feet (0.30, 0.61 and 1.22 m), respectively. Column IV was used as a control column to compare regenerated and virgin resin after the first regeneration.

Water flow through the aeration column in Phase I was set at 28 gal/min (6.4 m3/hr), corresponding to a residence time of about ten minutes. The air to water ratios used in Phase I were 30:1, 20:1, 15:1 and 5:1. To produce the desired air to water ratio, the air flow to the diffused aeration column was changed accordingly. To evaluate the effect of the off-gases on the ambient conditions, one day of air sampling, including ambient air and air exiting the diffused aeration column, was performed.

During the Phase I operation the resin columns became clogged due to accumulation of a reddish colored foreign matter, similar to rust, on the top of the resin in all columns. To prevent the accumulation of such material, a spiral wound nylon cartridge filter was installed in the influent line to the resin column.

Steam regeneration attempts during this phase indicated the need for additional steam capacity, shorter resin columns and counter-current application of steam and water. The Phase I pilot plant operations were completed on January 3, 1980.

The Phase II pilot plant operations were started on May 16, 1980. This phase continued the testing of adsorption using the same resin as Phase I, Rohm and Haas' Ambersorb ® XE-340, but utilized three pyrex-glass columns, each 2.2 feet (0.67 m) high having a diameter of 4 inches (0.10 m). The three resin columns in Phase II, designated Columns III, IV and V, each contained 2 feet (0.61 m) of resin and operated at a flow rate of 42 gallons/hr (0.16 m3/hr) producing an application rate of 4 gpm/ft3 (0.42 Lpm/m3) of adsorbent which corresponds to a 1.9 minute empty bed contact time. Column III contained resin which had been used in Phase I and the other two columns were replenished with virgin resin. The flow application for Column III was in a downflow mode, while Columns IV and V operated in the upflow mode. All steam regenerations were performed in a counter-current direction to the actual treatment flow.

Two 6-feet (1.83 m) pyrex glass columns, originally used in Phase I, were utilized in Phase II to evaluate the possibility of regenerating granular activated carbon with steam. These columns, designated Columns I and II, contained 4 feet (1.22 m) of granular activated carbon from ICI (H.D. 4000) and Calgon (Filtersorb 400), respectively. The flow to each column was 42 gal/hr (0.16 m3/hr) in a downward direction, resulting in an empty bed contact time of about 3.7 minutes which is actually less than half of the minimum empty bed contact time recommended by the activated carbon suppliers. This overloading condition was utilized during Phase II because the major objective of the granular activated carbon testing was the evaluation of regeneration by steam and not contaminant removal efficiency by activated carbon. Based on this objective it was decided to use this abnormally low empty bed contact time so that the activated carbon could be loaded with organics faster, requiring regeneration more frequently.

The air stripping testing in Phase II consisted of continuing the diffused aeration testing in the same manner described for PHase I, adding a packed diffused aeration column for comparison purposes, and evaluating a small cooling tower. The packed column diffused aeration column was operated at the same flow rate as the diffused aeration column, 28 gal/min (6.4 m3/hr) and air was supplied at the base of the packing using either six diffuser stones or through a three-inch diameter hole. Both methods of air induction were tested separately. The packed column diffused aeration column was tested using conditions which cause flooding, partial flooding and unflooding of the packing.

The cooling tower tested generated its own air draft. The air-to-water ratio from this tower was determined by field measurements and was varied by varying the water flow to the tower.

Steam regeneration was initially performed during normal working hours and the operation was shut down each night and restarted each morning until the predetermined time (24 hours for granular activated carbon) or condensate contaminant concentration (less than 100 ug/L for resin) was achieved. During this phase this procedure was then changed to continuous regeneration so that a comparison between interrupted and continuous regeneration could be compared. The use of "superloading" as a method of handling the condensate produced during steam regeneration was tested during Phase II.

During the latter part of Phase II the packing was removed from the second aeration column. The two diffused aeration columns were connected in series with a pump to transfer water from the first to the second column. The testing on this combination of columns were performed in an effort to determine a mass transfer coefficient and to evaluate the removal by second stage aeration. On January 30, 1981 the pilot plant operation of Phase II was completed.

After the required Phase III additions and modifications were made to the pilot plant facilities the testing operation was started on October 16, 1981. The aeration testing in Phase III consisted of continuing the diffused aeration system, adding an induced air spray aeration system, an air-lift pumping operation and testing of a packed column air-stripper designed and supplied by the U.S. EPA. This phase also included several samplings of air discharging the aeration units and ambient air to determine the impact of the air stripping units on the ambient environment.

The diffused aeration column was operated in the same manner as described for the previous phases except that it was operated continuously. The main reason for the operation of this column was to evaluate the effect of pre-aeration on the life of the resin.

The second aeration column used in Phase II was modified in Phase III so it could be utilized as an induced air spray aeration system. This system utilized a fan to induce ambient air and was operated with and without packing. The air to water ratio was varied by increasing or decreasing the water flow to the column.

A field-fabricated air-lift pump system was installed in Well No. 20. The air-lift pump received its air from blowers and the air to water ratio was varied by either changing the submergence of the air pipe in the well or varying the air supply.

U.S. EPA personnel tested their packed column air-stripping system at Glen Cove twice during Phase III. The column is approximately 18 feet (5.49 m) high and has a 24-inch (0.61 m) diameter. Water from Well No. 22 served as the influent to the column and the air to water ratio was varied by changing the blower speed and the influent water flow.

The resin testing in Phase III was designed to evaluate hydraulic loading, the effect of pre-aeration and the multi-regeneration of resin. To accomplish these objectives, seven pyrex glass columns of the same size used in Phase II were installed. Columns I through IV received water directly from Well 22, while Columns V, VI and VII received water which had been pretreated in the diffused aeration column. In all columns, except Column I which contained resin previously used in Phases I and II, two feet (0.61 m) of virgin XE-340 resin supplied by Rohm and Haas for Phase III were installed.

The system was operated using application rates from 2 gpm/ft3 (0.21 Lpm/ft3) to 8 gpm/ft3 (0.84 Lpm/ft3) of adsorbent to determine optimum hydraulic loading. After a short time, it became clear that resin performance during Phase III was much poorer than observed during Phases I and II. The problem was traced to improper particle distribution of the resin and a new batch was supplied.

One of the six-feet (1.83 m) pyrex columns, originally purchased for Phase I, was modified with sampling taps so that samples could be taken at one-foot (0.30 m) intervals. The column was filled to the four-feet (1.22 m) level with Calgon (Filtersorb 400) granular activated carbon and operated at a flow rate of 21 gph (0.08 m3/hr) in a downward direction resulting in an empty bed contact time of 7 minutes. Initially, sampling took place at the one-foot and two-feet sample taps. As contaminant breakthrough occurred, sampling was conducted at the remaining two sample taps.

The Phase III pilot plant was operated for fourteen months and terminated on December 16, 1982. A detailed discussion of the Phase III Testing Program and Operations is contained in the Phase III report which is presented in Appendix D of this final report.

SECTION 6

RESULTS

A. GENERAL

The pilot plant study at the Glen Cove, N.Y. site was operated for more than thirty-two months during the three phases of this study. This involved the analysis of numerous samples by the gas chromatograph both on and off site.

The influent for the majority of the testing devices was water from Well No. 22 which exhibited the highest concentration of contaminants when the project began. During this project there was noticeable shifting in the well water concentrations of cis-1,2-dichloroethylene, trichloroethylene, and tetrachloroethylene. During Phase I cis-1,2-dichloroethylene levels ranged from 18-118 ug/L, decreased to 28-79 ug/L in Phase II and increased to 71-216 ug/L during Phase III. The concentration of cis-1,2-dichloroethylene exhibited a fairly constant increase during the final phase. Trichloroethylene concentrations ranged in Phase I from 132-313 ug/L, decreased in Phases II and III to 117-277 ug/L, but showed a trend to the higher value during the end of Phase III. Tetrachloroethylene levels ranged from 18 to 92 ug/L in Phase I, increased greatly during Phase II from 32 to 207 ug/L, decreased greatly at the beginning of Phase III to about 40 ug/L and remained constant for the remainder of the period. The concentration of 1,1,1-trichloroethane remained constant over the three phases, ranging from 3 to 8 ug/L. This shift of contaminant concentrations could be due to the effect of soil on the individual contaminant or to introduction of new contamination.

The entire study program was hampered with constant breakdown of the gas chromatograph system (G.C.) supplied by Tracor, Inc. Throughout the entire project, the G.C. was out of operation for several periods causing backlogs in sample analysis. The results of each phase are detailed in the respective phase report. The following is a summary and comparison of those results.

B. RESIN ADSORPTION STUDIES - SUMMARY

Resin adsorption studies carried out during Phase I compared the effect of various resin bed depths on contaminant breakthrough and exhaustion service times. For the one-foot and two-feet (0.30 and 0.61 m) columns, breakthrough and exhaustion were observed to be proportional to resin bed depth. Although effluent contaminant levels were lower, the exhaustion of the four-foot (1.22 m) column was not observed to be proportional to bed depth and service time required for breakthrough.

Figures 11 and 12 for Phase I which are presented in Appendix A show the length of time that it took for a compound to reach a specified effluent concentration versus resin bed depth. Generally, disproportionately longer service times were required to reach the 5, 10, 25 and 50 ug/L effluent target levels in the deeper resin beds.

The Phase I Figure 12 shows that Ambersorb® XE-340 was most effective in adsorbing tetrachloroethylene and slightly better at adsorbing trichloroethylene than cis-1,2-dichloroethylene.

During Phase II, adsorption studies were performed at a constant depth of resin of 2 feet (0.61 m) and an application rate of 4 gpm/ft3 of adsorbent (0.42 Lpm/m3). Comparisons were made of the upward and downward flow application modes as well as the use of virgin and regenerated resins. Figure 9 of Appendix B of the Phase II report shows that downflow operation resulted in lowest contaminant levels and virgin resins in the same mode of operation performed slightly better than the regenerated resin. Other findings, consistent with those of Phase I, and graphs comparing the resin column's performance with respect to removal of the different contaminants can be found in the Phase II report (Appendix B).

Separate resin and aeration testing conducted during Phases I and II indicated that a system combining the two unit processes might be a desirable one for organic contaminant removal. Determination of the best and more economical mix of aeration and resin to achieve desirable water quality was studied during Phase III. Testing included the determination of the maximum hydraulic loading which could be applied to the resin.

Two resin adsorption systems, one receiving well water without prior aeration and the other receiving well water with prior aeration, were evaluated during Phase III. Initially, application rates of 2, 4, 6 and 8 gpm/ft3 (0.21, 0.42, 0.63 and 0.84 Lpm/m3) were used in the system evaluating direct treatment of the raw well water, and rates of 4, 6 and 8 gpm/ft3 (0.42, 0.63 and 0.84 Lpm/m3) used in the treatment approach combining aeration and adsorption. Similar contaminant removal patterns demonstrated by the resin during Phases I and II were again observed during Phase III when the acceptable resin was used. Resin saturation and exhaustion had a direct relationship to the applied hydraulic loading in both treatment system approaches. For air:water ratios of 8:1 and 15:1, resin service times were about five times longer for the pre-aerated well water than for the unaerated well water. Variance of service time required to achieve specified breakthrough levels is depicted in Figure 41 of the Phase III report. The higher quality effluents of the combined aeration-adsorption treatment approach are readily evident on these plots.

The optimum hydraulic loading to a resin adsorption system receiving water previously aerated must be determined by evaluating the hydraulic loading having a satisfactory service time and achieving the desired water quality and comparing the economics of the various hydraulic loadings. For more details concerning evaluation of the combined aeration-adsorption treatment system and determination of the optimum hydraulic loading of the resin refer to the Phase III report presented in Appendix C.

C. RESIN REGENERATION - SUMMARY

Initial regenerations during Phase I were done using a steam flow concurrent to that of the water flow. During these regenerations, cis-1,2-dichloroethylene was stripped from the resin by the steam more readily than the other major contaminants. It was believed that contaminant adsorption onto vacant sites in the lower portion of the resin bed was occurring as a result of the steam and operational water flow being in the same direction. For this reason, countercurrent steam regeneration was attempted, but was unsuccessful because of operational difficulties during the regeneration process. A solvent regeneration using methanol was used to complete the aborted steam regeneration.

Steam regenerations conducted in Phase I utilizing a steam rate of two bed volumes per hour indicated that the steam regeneration technique required further developing. Contaminant breakthrough with regenerated resin was observed to occur much earlier than with virgin resin. During Phase II, modifications to the steam regeneration system to eliminate steam condensation in the columns, evaluation of concurrent and countercurrent steam flow and investigation of the effect of greater steam loadings took place.

Improvements to enhance the degree of regeneration resulted in more successful regenerations in Phase II. High concentrations of organics stripped from the resin resulted in a phase separation between this layer and the aqueous steam condensate.

The percent regeneration, or percent of organics removed after being loaded on the media, was used as a measure of the success of a regeneration. While this was only an approximation, a high degree of success for Phase II regenerations was indicated. The steam rate utilized in Phase II was one bed volume per hour.

"Superloading", which is the practice of introducing the condensate from one regeneration cycle into the column to be regenerated next, was performed in Phase II as a solution to the problem of condensate disposal. The belief that "superloading" would further concentrate the organics and yield a larger organic phase was confirmed.

Further development of the steam regeneration technique during Phase III was prohibited because of the shortened length of time of resin studies done with acceptable resin. The percent of resin regenerated obtained for Phase III regenerations was significantly lower than for Phase II. While there was an improvement in the contaminant removal efficiency of the resin after a regeneration, breakthrough and saturation properties of the regenerated resins were not as favorable as for the virgin resins. The cause of the reduction in the adsorbent capacity of the regenerated resin is apparently due to the relatively low percent regeneration.

Speculation as to why the Phase III regenerations were not as successful as those done during Phase II is possibly related to the length of time the regenerations were carried out. All regenerations were conducted by passing two bed volumes of steam per hour through the resin column. When the total contaminant level in the condensate, which was being monitored while the regeneration was in progress, dropped below the 100 mg/L level, the regeneration was stopped. This took place after 12 and 13½ hours for the two regenerations in Phase III. Earlier regenerations at the steam rate of one bed volume of steam per hour required 20 to 30 hours before the level was reached. Although the regenerations were stopped when the contaminant levels in the condensate reached the predetermined level, the shorter Phase III regenerations did not strip as much of the contaminants which had been loaded onto the resin as those carried on for longer periods of time. This lower removal of contamination from the resin bed could have been due to the higher steam rate and lower time utilized for regeneration during Phase III.

In an effort to determine what effects multiple regeneration would have on resin performance,one 0.17 ft3 (5 liters) batch of resin was used in all three phases. Based on laboratory studies conducted bv Rohm and Haas, the manufacturer of Ambersorb ® XE-340, the resin was shown to be steam regenerable for many cycles. However, these laboratory studies had been carried out on a surface water supply from which primarily chloroform was removed by the resin. The shortage of laboratory data pertaining to the steam regeneration of the resin for removal of the organic contaminants of concern in Glen Cove, and the determination of the success of multiple regenerations at restoring a useful percentage of virgin resin adsorbent capacity under actual field conditions warranted evaluation.

The column containing this resin was designated as Column II in Phase I, Column V in Phase II and Column I in Phase III. The columns containing the 0.17 ft3 (5 liters) of resin had 2 ft (0.61 m) of depth in all phases. The testing in all three phases utilized a 4 gpm/ft3 (0.42 Lpm/m3) application rate, equivalent to 1.9 minute empty bed contact time and 722.1 bed volumes per day. The mode of column operation, however, varied from phase to phase. In Phase I both water flow and the direction of steam regeneration were in the downward mode; in Phase II flow application was upward with countercurrent steam regeneration; and in Phase III a downward flow mode with countercurrent steam regeneration was used.

During the three phases, multiple regenerations of the same resin took place eight times (seven times with steam and once with solvent, methanol) and the contaminant removal efficiency of the resin was evaluated for each of the nine subsequent cycles. The data for all but one of the regenerations are summarized in Table 1. Although percentage regeneration values are approximations due to the estimation of the amount of organics in the non-aqueous phase produced during a regeneration, they serve as useful measures of the success of a regeneration. The regenerations conducted during Phases I and II were more successful in terms of the percentage regeneration

$$\left(\frac{\text{total contaminant removed}}{\text{total contaminant loaded}} \times 100\right)$$

of the resin than those which were performed during Phase III. The lower Phase III percentage regenerations are attributable to the cumulative effect of the organics remaining in the resin after each successive regeneration. It is also apparent that the large amounts of organics which couldn't be removed from the resin contributed to the deterioration of the adsorbent capacity of the resin resulting in the rapid breakthroughs and high effluent levels seen during Phase III.

Examination of the breakthrough curves in Figures 1-3 for the three major contaminants shows a progressive deterioration of resin adsorbent capacity with continued use of the rein. The breakthrough curves for cis-1,2-dichloroethylene and trichloroethylene best exemplify this. It is also evident from the curves that the length of time of column operation required before breakthrough is apparent decreases as the number of regenerations which the resin has undergone increases. Breakthrough and resin saturation were observed to take place most

TABLE 1

GLEN COVE, N.Y. - PILOT PLANT - RESIN COLUMN MULTI-CYCLE REGENERATION

SUMMARY OF RESULTS

	Phase I		Phase II		Phase III		
Column Number	II		V			I	
Resin Bed Volume (liters)	5		5			5	
Direction of Water Flow	Down		Up		Down	Down	Down
Direction of Steam	Down		Down		Up	Down	Up
Regeneration	First	Second	Third	Fourth	Sixth	Seventh	Eighth
Dates	10/30- 11/2/79	5/19- 5/20/80	9/2- 9/3/80	1/14- 1/15/81	2/2- 2/3/82	6/3- 6/4/82	10/28- 10/29/82
Calculated Bed Volumes of Water Passed until Regeneration	67,278	23,021	76,438	83,315	79,452	91,285	103,787
Bed Volumes of Steam Used	67	18½	30	22	22 3/4	8 3/4 (acetone)	18½
Loading - Carryover (g)*	-	10.9	19.2	58.1	44.3	79.5	90.5
Organics in Water (g)**	92.8	36.8	79.1	113.5	79.6	95.3	98.6
Superloading (g)***	-	-	-	28.9	-	-	-
Total Loading (g)	92.8	47.7	98.3	200.5	123.9	174.8	189.1
Organics Removed - Aqueous Phase (g)	81.9	20.1	38.7	36.2	34.7	84.3 (solvent phase)	24.1
Estimated Volume - Organic Phase (ml)	0	6	1	80	6.5	-	22.5
Mass of Organic Phase (g)	0	9	1.5	120	9.7	-	33.5
Total Removed (g)	81.9	29.1	40.2	156.2	44.4	84.3	57.6
Organics Remaining (g)	10.9	18.6	58.1	44.3	79.5	90.5	131.5
Percentage Regeneration****	88 %	61 %	41 %	78 %	36 %	48 %	30 %

* Organics remaining in resin after previous regeneration

** Organics removed from water during run prior to regeneration

*** Organics placed in resin due to superloading procedure

**** Percentage Regeneration = $\frac{\text{Total Removal}}{\text{Total Loading}} \times 100$

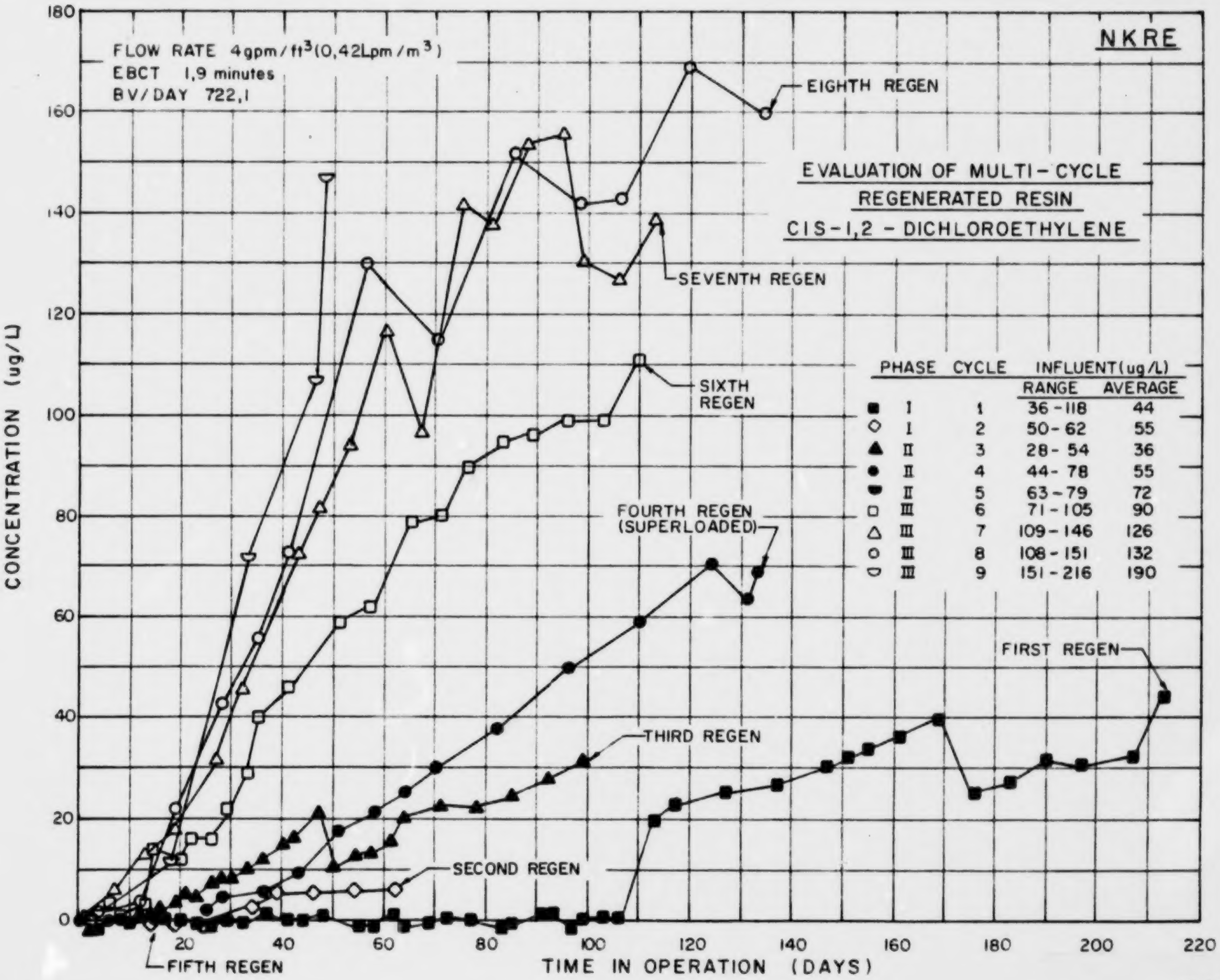
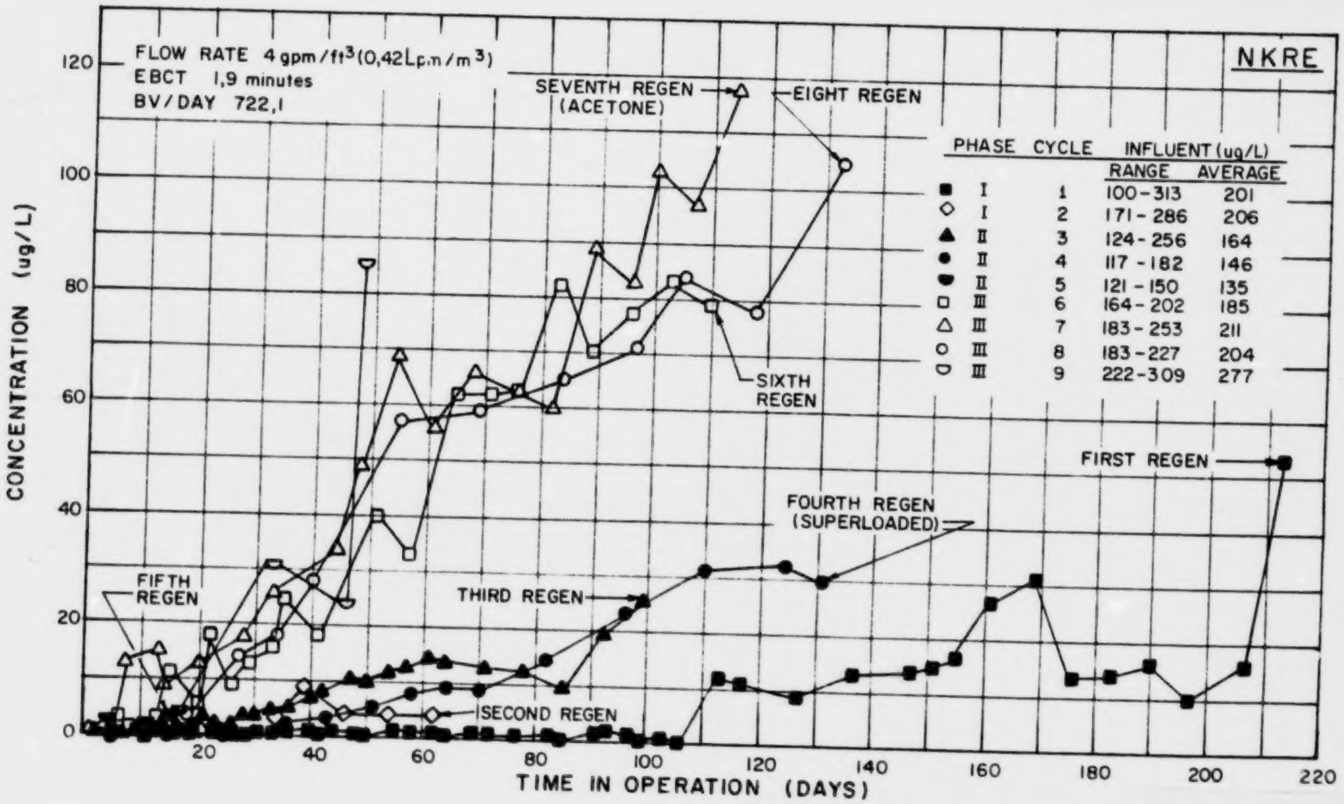

NKRE
FLOW RATE 4gpm/ft³(0,42Lpm/m³)
EBCT 1,9 minutes
BV/DAY 722,1
EVALUATION OF MULTI-CYCLE
REGENERATED RESIN
CIS-1,2 - DICHLOROETHYLENE
PHASE CYCLE INFLUENT(ug/L)
RANGE AVERAGE
■ I 1 36-118 44
◇ I 2 50-62 55
▲ II 3 28-54 36
● II 4 44-78 55
◒ II 5 63-79 72
□ III 6 71-105 90
△ III 7 109-146 126
○ III 8 108-151 132
▽ III 9 151-216 190
EIGHTH REGEN
SEVENTH REGEN
SIXTH REGEN
FOURTH REGEN (SUPERLOADED)
THIRD REGEN
SECOND REGEN
FIRST REGEN
FIFTH REGEN
CONCENTRATION (ug/L)
0
20
40
60
80
100
120
140
160
180
TIME IN OPERATION (DAYS)
20
40
60
80
100
120
140
160
180
200
220

FIGURE I



EVALUATION OF MULTI-CYCLE REGENERATED RESIN
TRICHLOROETHYLENE

FIGURE 2

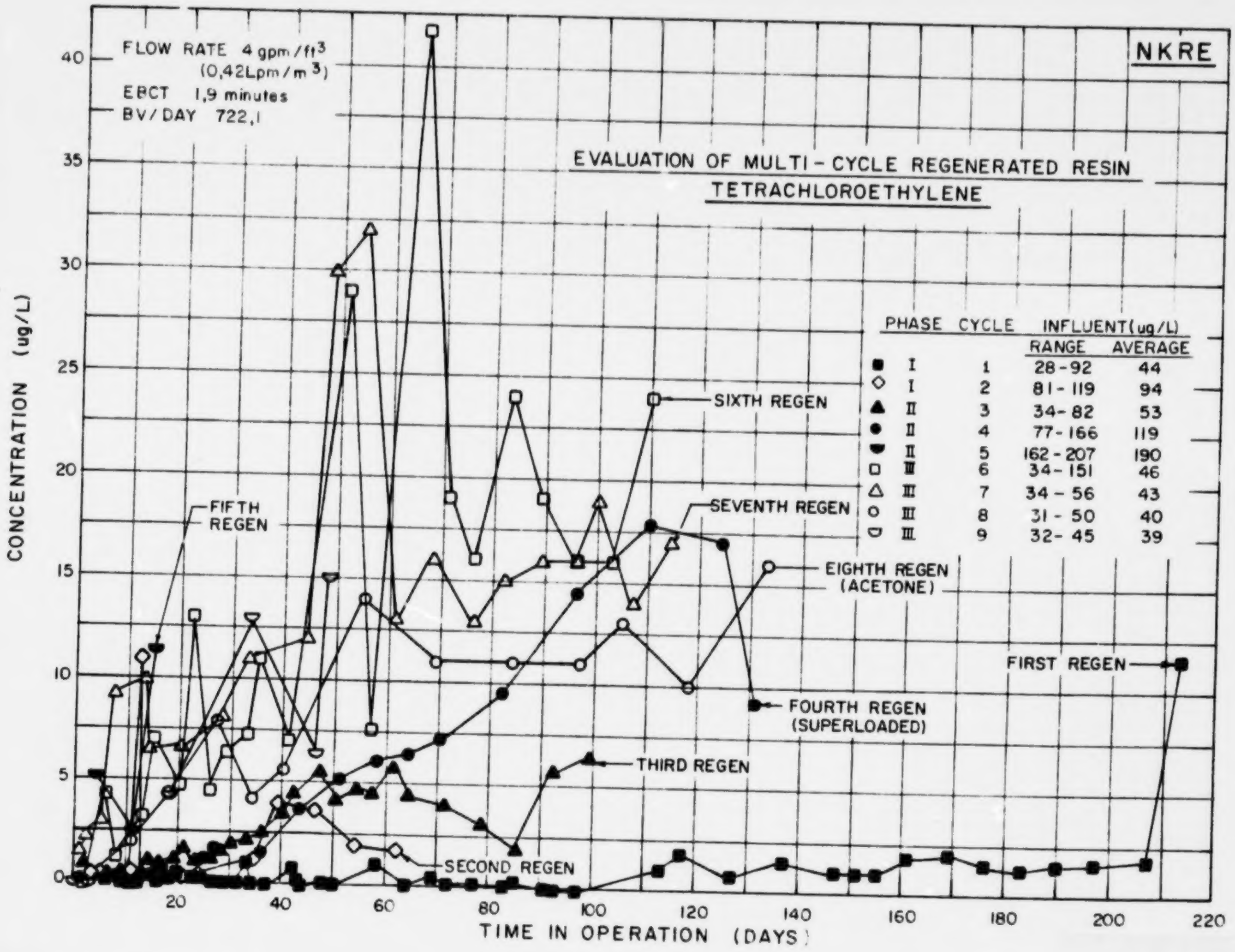

NKRE
EVALUATION OF MULTI-CYCLE REGENERATED RESIN
TETRACHLOROETHYLENE
FLOW RATE 4 gpm/ft³
(0,42Lpm/m³)
EBCT 1,9 minutes
BV/DAY 722,1
PHASE CYCLE INFLUENT(ug/L)
RANGE AVERAGE
■ I 1 28-92 44
◇ I 2 81-119 94
▲ II 3 34-82 53
● II 4 77-166 119
▼ II 5 162-207 190
□ III 6 34-151 46
△ III 7 34-56 43
○ III 8 31-50 40
▽ III 9 32-45 39
FIRST REGEN
SECOND REGEN
THIRD REGEN
FOURTH REGEN
(SUPERLOADED)
FIFTH
REGEN
SIXTH REGEN
SEVENTH REGEN
EIGHTH REGEN
(ACETONE)
CONCENTRATION (ug/L)
0
5
10
15
20
25
30
35
40
TIME IN OPERATION (DAYS)
20
40
60
80
100
120
140
160
180
200
220

FIGURE 3

rapidly during Phase III, which corresponded to the fifth, sixth and seventh regenerations of the resin.

The lower percentage regenerations of Phase III were caused by the cumulative effect of the organics remaining in the resin after successive regenerations. The carryover of organics from regeneration to regeneration was the major cause of the deterioration of the resin's adsorbent capacity.

For the seventh regeneration solvent (acetone) was used instead of steam. According to the resin manufacture solvent regeneration was, theoretically, supposed to restore 100 percent of the resin's virgin adsorbent capacity. Contaminant removal efficiencies shown by the resin after regeneration with solvent did not substantially improve the resin's adsorbent capacity. It should be noted that the solvent was applied in the same direction as the influent (concurrent regeneration). The regeneration with solvent may require countercurrent regeneration as proved best for steam regeneration.

It should be noted that the resin used in all three phases went through several changes of testing containers and modes of operation which may have had an influence on the regenerability of the resin. A true evaluation of the regenerability of the resin would require a long-range application study under constant conditions over many cycles of operation.

D. GRANULAR ACTIVATED CARBON STUDIES - SUMMARY

Determination of the regenerability of spent granular activated carbon (GAC) with steam was the objective of Phase II testing using ICI (H.D. 4000) and Calgon (Filtersorb 400) granular activated carbons.

The column containing the ICI activated carbon was regenerated twice. The percent regenerations obtained were 30 percent for the first and 24 percent for the second. The faster breakthroughs after each regeneration for cis-1,2-dichloroethylene, 1,1,1-trichloroethane, and trichloroethylene than the previous cycle were the outcome of these partially successful regenerations.

The column containing Calgon activated carbon was regenerated once and 36 percent regeneration was obtained. As with the ICI activated carbon, earlier breakthroughs were observed in the cycle following the regeneration.

The results of the three 24-hour carbon regeneration attempts, utilizing the steam equipment and conditions designed to regenerate resin, showed little success under the conditions tested.

A column containing granular activated carbon was used in Phase III to study the movement or wavefront of the different contaminants through the carbon bed. Computation of the time in days per foot per ug/L of contaminant to achieve different concentration levels showed that cis-1,2-dichloroethylene (0.15 days per ft per ug/L) penetrated the carbon bed the fastest, and 1,1,1-trichloroethane (16.2 days per ft per ug/L) the slowest. Trichloroethylene (0.35 to 0.76 days per foot per ug/L) and tetrachloroethylene (9.3 to 15.6 days per foot per ug/L) penetration rates were observed to be intermediate. Desorption of cis-1,2-dichloroethylene, trichloroethylene, and 1,1,1-trichloroethane was observed when the compound's concentration at the sampling tap was greater than its concentration in the influent to the column.

E. AERATION STUDIES

1. General

The aeration studies were performed during all three phases. At the beginning of this project very little was known about the ability of air stripping procedures to remove volatile organic contaminants from a drinking water supply. It was only after preliminary testing using aeration at the Carney well site (funded by the City of Glen Cove)(1) and aeration testing on spiked distilled water (U.S. EPA, Cincinnati, Ohio)(4) that they were included as a part of this research project.

Unlike other treatment technologies, such as adsorption, aeration does not require recovery, regeneration, or chemicals and does not produce a waste product for disposal. Therefore, it should have little or no impact on the environment in most areas. During the three phases of the Glen Cove study several aeration approaches were tested. These included diffused aeration, packed column diffused aeration, cooling tower, induced air spray aeration, packed column air-stripping and air-lift pumping. The results of each approach will be summarized in this section.

2. Diffused Aeration Studies

The diffused aeration method was the only approach tested during all three phases. This testing was accomplished using a 30-inch (0.76 m) diameter 10 feet (3.05 m) high column with a water level maintained at 8 feet (2.44 m) from the bottom and the air induced by spargers about 2 feet (0.61 m) from the column bottom. Diffused aeration testing in Phase I was performed using air to water ratios of 30:1, 20:1, 15:1 and 5:1. The results, which are summarized on Figure 17 of the Phase I report presented in Appendix A, show that diffused aeration at air to water ratios of at least 15:1 would meet the current New York State guidelines of 50 ug/L per contaminant and 100 ug/L for all organic contaminants. A complete discussion of the Phase I results is presented in the Results section of the Phase I report (EPA-600/2-80-198).

The diffused aeration studies in Phase II included the same diffused aeration column utilized in Phase I and a new identical column with packing so that the principle of packed column diffused aeration could be evaluated. Both systems were tested at an air to water ratio of 15:1, 10:1 and 5:1. The packed column diffused aeration system was first tested with the packing flooded, that is completely under water. The flooding was decreased in stages until the total 6 feet of packing was above the water level and water was trickling through the packing. Air was introduced below the packing by two methods, either by air spargers or a hole in an air pipe. During the last stages of Phase II the packing from the second column was removed and the two columns were operated in series as diffused aeration columns.

The results of the diffused aeration testing in Phase II confirmed the results of Phase I, that the diffused aeration system could meet present New York State guidelines at air to water ratios of 15:1 or higher. Tests conducted on the packed column diffused aeration system indicated that this system operated best using unflooded packing, producing a slightly better water quality than plain diffused aeration. The two stage diffused aeration testing, which was mainly run to determine a mass transfer coefficient for diffused aeration, indicated that second stage diffused aeration continues the air stripping process and improves the effluent water quality.

In general, the overall removal of contaminants for the diffused aeration column was 84 percent at an air to water ratio of 15:1. This removal efficiency was improved to an overall average $>$ 90 percent by the two-stage aeration. The packed column diffused aeration system under the unflooded conditions had an overall removal of 83 percent using a 10 to 1 air to water ratio. These results of Phase II are summarized on Phase II Figures 11, 12 and 17 and Phase II Tables 1, 3 and 5 which are presented in Appendix B. A complete discussion of the Phase II data is presented in the Results section of the Phase II report (EPA-600/2-82-027).

The diffused aeration testing in the Phase III section of this project was mainly performed to pretreat the water before resin adsorption so this combined approach could be evaluated. Since the diffused aeration system actually operated as an individual unit the results of the testing in Phase III were evaluated separately. The system was tested using air to water ratios of 5:1, 8:1 and 15:1. The results of this testing again indicated the ability of diffused aeration to meet present New York State guidelines at an air to water ratio of 15:1. A more detailed discussion of the diffused aeration in Phase III is presented in the Phase III report contained in Appendix C of this final report.

3. Cooling Tower Studies

The induced draft cooling tower used in Phase II was a small demonstration unit and, therefore, no air to water ratio data were available. The actual air to water ratios were determined in the field by air and water flow measurements. The unit was actually operated at an air to water ratio ranging from 350:1 to 600:1. The average values for influent, effluent and percent removals are presented on Table 2 of the Phase II report excerpts (Appendix B). The data indicate that the highest average contaminant removal was about 62%, which was the lowest average removal efficiency achieved by the three aeration methods tested in Phase II.

4. Air-lift Pumping Studies

A field fabricated air-lift pump was installed in Well No. 20 during the Phase III study period. The air to water ratio was varied by increasing or reducing either the length of the air pipe in the well or the volume of air supplied to the well by the blowers. Based on the limited data available before the beginning of Phase III, the pumping system was designed at a minimum air to water ratio of 10:1 and a pump production of 50 gpm (190 Lpm). The results of the testing during Phase III indicate an average overall contaminant reduction of about 50%. A review of the data and the Phase III operating conditions and methods shows that the air-lift pump was not operated under optimum conditions. A detailed presentation of the results of the air-lift pumping study is contained in the Results section of the Phase III report which is presented in Appendix C of this final report.

5. Induced Air Spray Aeration Studies

The induced air spray aeration system tested during Phase III utilized the column used in Phase II for the packed column diffused aeration study. This column was modified so that ambient air could be induced near its base utilizing a fan mounted on the top of the column. The initial approach was the study of several spray systems using nozzles. As the testing proceeded packing was added to the column. Air to water ratios of between 450:1 and 12,000:1 and natural draft conditions were utilized during the Phase III testing. The results of the induced air spray aeration studies indicated that removals between 50 and 75 percent were achievable using the plain spray nozzles. This removal efficiency was greatly improved when packing was added to the column, exceeding 90 percent overall removal of contaminants. Present New York State

Guidelines were exceeded with the plain spray nozzles but were met when packing was installed. The natural draft approach tested utilized the conditions without packing and 4 feet (1.22 m) of packing. The testing without packing produced poor results removing between 43 to 63 percent of the contaminants; however, when the packing was added, the percent removal increased to greater than 80 percent. The nozzles without packing may achieve desirable levels utilizing a very high tower. The evaluation of a high tower was not possible during Phase III because of the equipment and pilot plant configuration. A detailed discussion of the induced air spray aeration system results is presented in the Results section of the Phase III report contained in Appendix C of this final report.

6. Packed Column Air Stripper

During the Phase III pilot plant period U.S. EPA personnel installed and operated their packed column air stripper test unit at the Glen Cove site. This column had 18 feet (5.5 m) of packing material and both 1-inch (2.5 cm) and 2-inch (5.0 cm) plastic saddles were independently used as packing. Air was induced through a bottom opening using a blower to cause a vacuum. During the two evaluation periods several air to water ratios ranging from 5:1 to 85:1 were tested. The overall contaminant removals ranged from about 63 percent to greater than 95 percent. The unit was tested twice using a natural draft. This did not appear successful, achieving a much lower overall percentage removal. A detailed discussion of the results of the packed column air stripper testing in Phase III is contained in the Results section of the Phase III report presented in Appendix C of this report.

7. Air Sampling

Since the air discharging any aeration treatment system mixes with the ambient air in the vicinity of the treatment plant, the effect on the ambient air was evaluated during Phases I and III. This evaluation was accomplished by sampling and analyzing the air discharging each aeration unit tested and the ambient air. The results, which are presented in detail in the Results sections of the Phase I and Phase III reports, indicate no appreciable impact on the ambient conditions.

8. Particulate/Suspended Solids Measurements

The effect on water quality of introducing ambient air in aeration systems was partially examined during Phase III. Influent and effluent particulate and suspended solids analyses were made for the aeration systems that utilized ambient air. The results of this testing, which are presented in detail in the Results section of the Phase III report, indicate little to no effect on the treated water quality. It should be noted that the ambient air in the Glen Cove area is relatively clean and the effect may be positive in an area where air pollution is present.

9. Aeration Studies - Summary

The data developed during the three phases for all six aeration methods tested during this research project are compared and summarized on Table 2. This summary indicates that the best removals were achieved by the packed column air stripper closely followed by the induced air spray aeration system with packing. The lowest overall removal was achieved by the air-lift pumping system. In general, an aeration approach can be used to meet drinking water quality in most areas.

TABLE 2

SUMMARY OF AVERAGE OVERALL PERCENTAGE REMOVAL FOR AERATION METHODS TESTED AT GLEN COVE, N.Y.

System	Range of Overall Percentage Removal**
1. Diffused Aeration	
A. Single Stage	59 - 84
B. Two Stages	86 - 96
2. Packed Column Diffused Aeration	70 - 83
3. Induced Draft Cooling Tower	53 - 61
4. Induced Air Spray Aeration	
A. Without Packing	
- Induced Air	52 - 77
- Natural Draft	43 - 63
B. With 2 ft (0.61 m) Packing	
- Induced Air	80 - 82
C. With 4 ft (1.22 m) Packing	
- Induced Air	91 - 93
- Natural Draft	81*
5. Packed Column Air Stripper	
A. With 1-inch (2.5 cm) Saddles	
- Induced Air	69 - 97
- Natural Draft	38*
B. With 2-inch (5.0 cm)	
- Induced Air	63 - 95
- Natural Draft	72*
6. Air-lift Pumping	46 - 56

* Results based on one day of testing
** Function of air to water ratio.

SECTION 7

ESTIMATED FULL-SCALE INSTALLATION COSTS

A. ADAPTABILITY OF SYSTEMS

1. Resin Systems

The resin system can be designed and installed using a flow application rate of 4 gpm/ft3 (0.42 Lpm/m3). This system would produce a very high quality of water supply and can be regenerated on-site using steam. The handling of the steam condensate was not fully developed during the research period and until a better and more economical method is proven the condensate could be hauled to an approved chemical disposal site. The other major problem with this treatment approach is that the manufacturer (Rohm and Haas) of the XE-340 adsorbent has halted commercial production of the material.

2. Diffused Aeration System

The results of the testing in all three phases indicates that a full-scale diffused aeration system can be designed and installed. The system would be capable of producing a water quality which would meet present New York State guidelines and one that would be acceptable in most areas.

3. Packed Column Diffused Aeration System

The packed column diffused aeration system can produce an equivalent or better water quality than the diffused aeration system, so the same statements made for diffused aeration apply to packed column aeration.

4. Induced Air Packed Spray Aeration System

While this approach produced a better water quality than the diffused aeration systems, optimum design parameters such as hydraulic loading were not determined during this research project. Before an actual full-scale plant is designed and installed these design parameters should be determined so that the most economical system would be utilized.

5. Packed Column Air Stripper

This approach, which produced the best overall removal results of all aeration methods tested, can be designed and installed on a full-scale basis. However, further evaluation of the ambient air impact on the effluent water quality should be made.

6. Air-lift Pumping

The testing during this project did not indicate that this system was a viable method to produce acceptable drinking water quality. It should be noted that this system was not operated under optimum conditions during this project and further evaluation should be accomplished before a final decision on this method is made.

7. Combined Aeration - Resin System

The Phase III testing indicates that the pretreatment of the water by aeration will lengthen the operating cycle of a resin system. The results of the combined testing in Phase III indicates that 4 gpm/ft3 (0.42 Lpm/m3) would be the optimum application rate with or without prior aeration. Because of this it is necessary to install complete aeration and resin systems.

B. ESTIMATED COSTS FOR FULL-SCALE INSTALLATIONS

The estimated costs for full-scale treatment were based on flow rates of 1, 2 and 5 mgd (3,785, 7,575 and 18,925 m3/day) in all three phases. These flow rates were utilized to obtain a range of costs for full-scale installations for the following systems: diffused aeration, packed column diffused aeration, induced air packed column spray aeration, packed column air-stripping, air-lift pumping, and resin without prior aeration. The latest detailed cost estimates for all systems except packed column diffused aeration are presented in Phase III report contained in Appendix C. An updated detailed cost for packed column diffused aeration system is presented in Appendix B which contains sections from the Phase II report. All costs in the reports were estimated by NKRE personnel using the most recently available costing information in February 1983. All the estimated costs include required buildings for mechanical and electrical equipment but not laboratory, offices or facilities for workmen.

The capital cost for five of the aeration systems tested during this research project, single stage diffused aeration, packed column diffused aeration, induced air packed column spray aeration, packed column air-stripper and air-lift pumping along with the capital cost for the resin system are compared on Figure 4. These estimated capital costs indicate that the packed column air-stripper system has the lowest capital cost and the resin system has the highest capital cost. A comparison of the annual operating cost per 1000 gallons (3,785 liters) of treated water considering an electrical cost of $0.09/kWh for all systems indicated above is presented on Figure 5. The estimated annual operating cost for the systems show that the packed column air-stripping system has the lowest operating cost while the air-lift pump system has the highest operating costs. A complete detailed discussion of the estimated costs for full-scale treatment systems are presented in the Cost section of the reports for each phase.

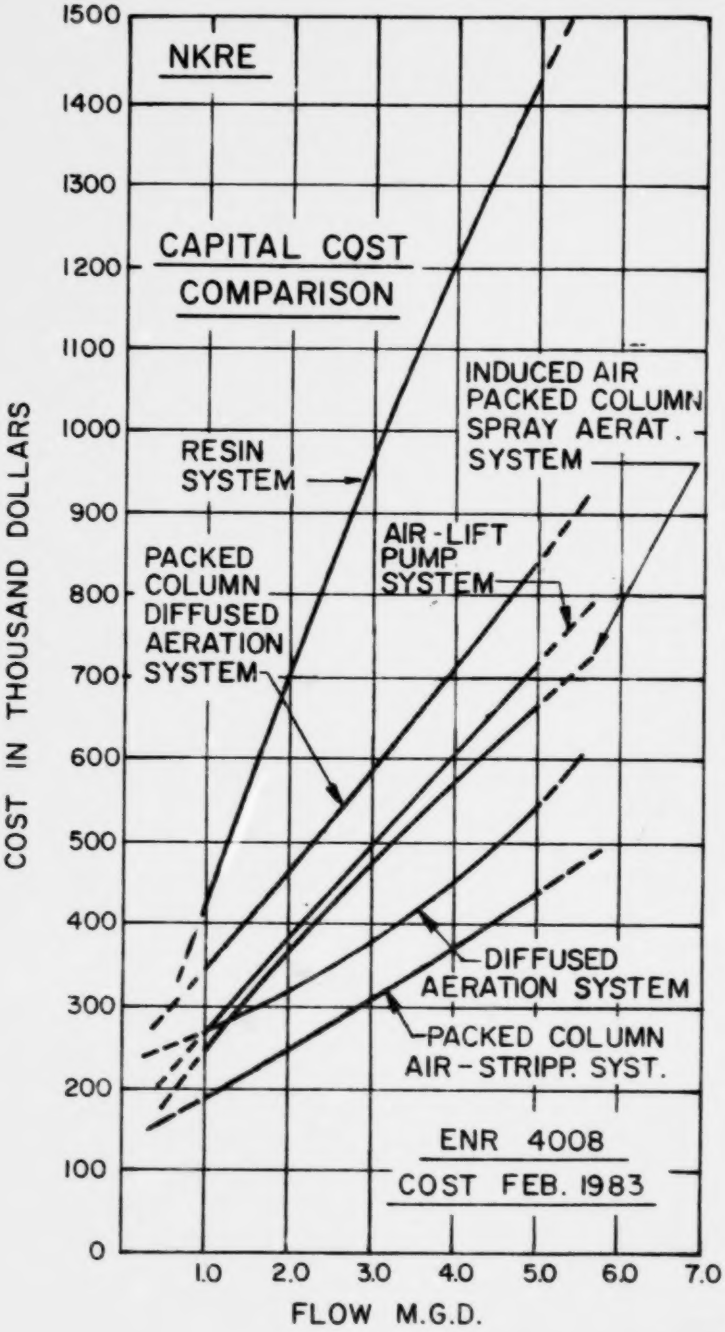

NKRE
CAPITAL COST
COMPARISON
COST IN THOUSAND DOLLARS
FLOW M.G.D.
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1.0
2.0
3.0
4.0
5.0
6.0
7.0
RESIN SYSTEM
INDUCED AIR PACKED COLUMN SPRAY AERAT. SYSTEM
AIR-LIFT PUMP SYSTEM
PACKED COLUMN DIFFUSED AERATION SYSTEM
DIFFUSED AERATION SYSTEM
PACKED COLUMN AIR-STRIPP. SYST.
ENR 4008
COST FEB. 1983

FIGURE 4

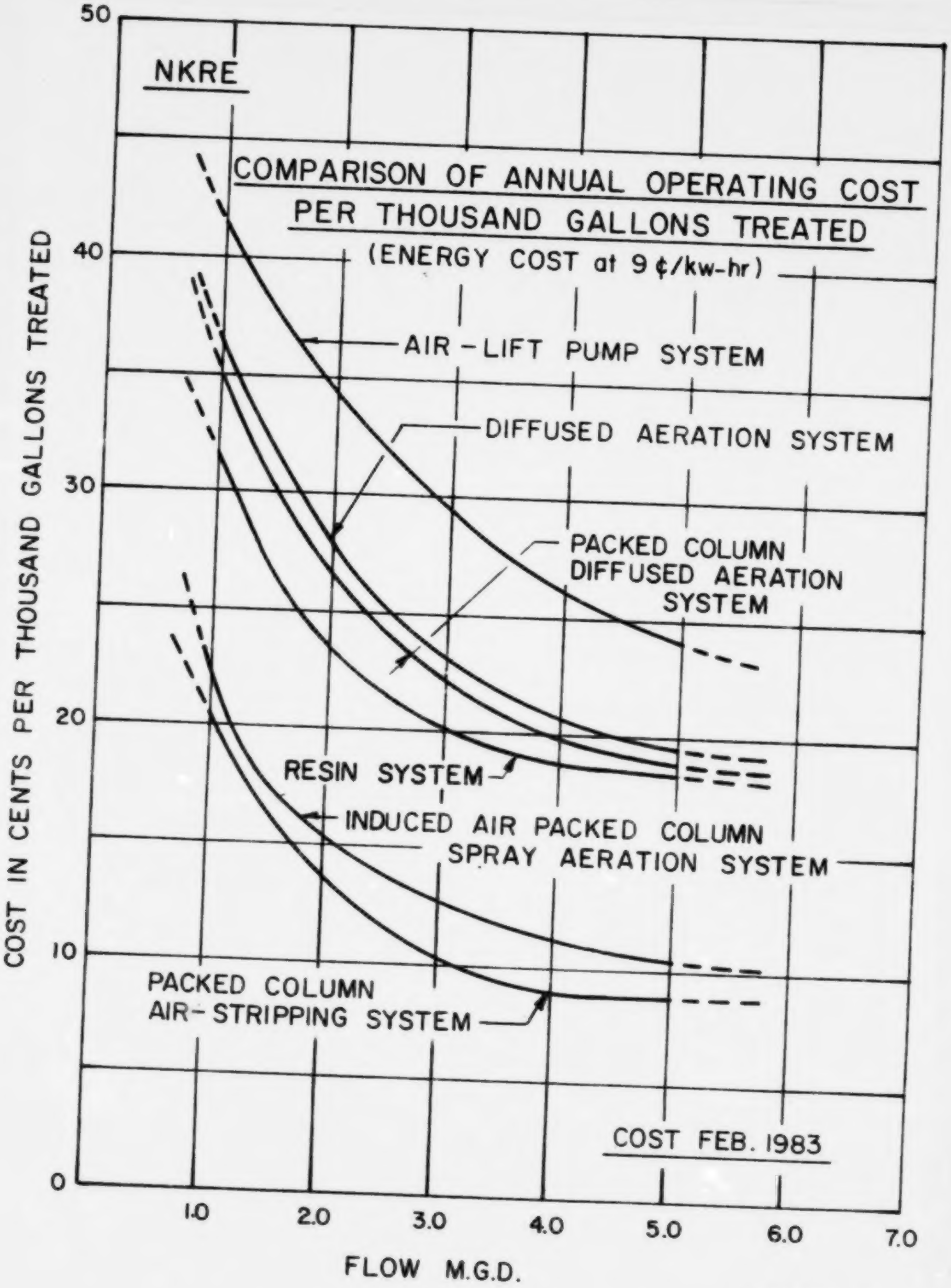

NKRE
COMPARISON OF ANNUAL OPERATING COST PER THOUSAND GALLONS TREATED
(ENERGY COST at 9 ¢/kw-hr)
AIR - LIFT PUMP SYSTEM
DIFFUSED AERATION SYSTEM
PACKED COLUMN DIFFUSED AERATION SYSTEM
RESIN SYSTEM
INDUCED AIR PACKED COLUMN SPRAY AERATION SYSTEM
PACKED COLUMN AIR-STRIPPING SYSTEM
COST FEB. 1983
COST IN CENTS PER THOUSAND GALLONS TREATED
0
10
20
30
40
50
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 5

APPENDIX A

PHASE I REPORT (EPA-600/2-80-198)

EXCERPTS

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REMOVAL OF ORGANIC CONTAMINANTS FROM DRINKING WATER SUPPLY AT GLEN COVE, N.Y.

Phase I

by

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U.S. EPA Cooperative Agreement No. CR 806355-01

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SECTION 1

INTRODUCTION

The City of Glen Cove, New York, located on the north shore of Nassau County, Long Island, receives its drinking water supply from a series of wells located throughout the City. Even though Long Island is part of New York State and parallels the southern coast of New England it is separated from the mainland by a salt water body, Long Island Sound. Therefore, the water supply to most of the communities on the Island is limited to wells since they do not have easy access to the watersheds on the mainland. Communities such as the City of Glen Cove, which depend on underground aquifers as the sole source of their water supplies, are greatly affected by contamination of these underground supplies.

The Glen Cove water supply system, which has a normal demand of approximately 3 million gallons per day (11,355 m^3/day) and 8 million gallons per day (30,280 m^3/day)during peak summer months, consisted of nine (9) wells designated as Duck Pond Rd. Wells Nos. 1 and 2, Seaman Rd. Wells Nos. 1 and 2, Morgan Island Well, Roxbury Well and Carney Street Wells Nos. 20, 21, and 22. These wells were capable of delivering more than an ample supply to meet peak requirements. However, analyses performed in the summer of 1977 by the Nassau County Department of Health, indicated that the water from Seaman Rd. Well No. 1 and Carney Street Wells Nos. 20, 21 and 22 contained trichloroethylene and tetrachloroethylene concentrations above New York State's maximum allowable limits of 50 micrograms per liter (ug/l) for any one organic contaminant and a total allowable limit of 100 ug/l for all such compounds. Therefore, the use of these wells was restricted by the County Health Department.

Faced with the problem of reduced water supply, the City of Glen Cove began evaluating methods to augment their reduced supply to a normal capacity level, and arranged to purchase water from adjoining communities until an adequate supply could be reestablished. To regain a sufficient supply of well water, the City decided on two approaches: the drilling of new wells in a non-contaminated area, and the definition of a treatment system which would render the water in contaminated wells usable.

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The City retained the consulting engineering firm of Nebolsine Kohlmann Ruggiero Engineers, P.C. (NKRE) for the determination of a feasible and economical treatment system. Through consultation with the U.S. EPA's Drinking Water Research Division, Municipal Environmental Research Laboratory (MERL), Cincinnati, it was determined that no existing treatment system was capable of treating the large volumes of water containing these organic contaminants. After some preliminary testing of the Carney St. wells, discussions and negotiations between the City, NKRE and the U.S. EPA resulted in a research grant (later a cooperative agreement) funded by the U.S. EPA to test several possible treatment methods at the Glen Cove site.

The pilot plant testing program was conducted from March 28, 1979 to January 3, 1980 and consisted of the evaluations of synthetic resin and diffused aeration for the removal of organic contaminants present in Glen Cove's drinking water supply.

SECTION 2

CONCLUSIONS

RESIN ADSORPTION STUDIES

1. Test results using Rohm and Haas' Ambersorb XE-340 indicated that this resin was capable of reducing the levels of the contaminants to below existing New York State guidelines. In most cases, virgin resins achieved reduction of each contaminant to less than 1 ug/l, for the following influent concentration ranges: cis-1,2-dichloroethylene, 18-118 ug/l; trichloroethylene, 132-313 ug/l; 1,1,1-trichloroethane, 3-8 ug/l and tetrachloroethylene, 18-92 ug/l.

2. Generally, the order of breakthrough was cis-1,2-dichloroethylene, trichloroethylene, then tetrachloroethylene for empty bed contact times (EBCTs) of 1.9 and 3.8 minutes. Once the cis-compound broke through, it continued to leak at a much faster rate than the other compounds.

3. The target level is an important consideration in interpretation of the data. For an EBCT of 1.9 min., times in service to achieve an effluent level of 25 ug/l were: 65 days for the cis-compound, 108 days for trichloroethylene, and 170 days for tetrachloroethylene. However, if maintaining an effluent level of 5 ug/l, for example, is desired, the respective times become 40 days, 48 days, and 85 days.

4. The breakthrough and exhaustion of the resin occurred proportionately to depth for the one and two foot columns based on cis-1,2-dichloroethylene. This was not the case for all contaminants and therefore no true conclusion can be made as to the effect of bed depth.

5. Steam regeneration techniques require further testing before recommended techniques can be made. The testing of the methods of regenerating the resin did not produce a definite conclusion. While regeneration with steam appeared promising, the results achieved in the laboratory by the resin manufacturer could not be duplicated under pilot plant conditions. Contaminant breakthrough with

"regenerated" resin occurred much earlier than with virgin resin, probably because the regeneration had not been completely successful.

6. During this program, the Carney St. well operated almost continuously for a 250-day period. When pumping began, the contaminant levels were low, but increased steadily over the first 10 days. In subsequent days, although concentrations of the various contaminants varied, overall concentrations remained high.

7. The resin manufacturer's estimated capital costs of a full scale resin installation for plant capacities from 1-5 mgd (3,785-18,925 m^3/day) range from \$420,000 to \$1,200,000, based on two columns operating in series having an application rate of 4 gpm/ft^3 (0.42 lpm/m^3) on an empty bed contact time of 2 minutes. The estimated total annual operating cost, including amortization, is about \$0.18-\$0.31 per 1,000 gallons (3.79 m^3) of treated water. This cost is based on Glen Cove's comparatively high electrical costs, and may be lower in other areas. These costs do not include the cost of disposing and/or handling of the waste regenerant since no system for this has been demonstrated.

DIFFUSED AERATION STUDIES

1. Aeration reduced the tested contaminants below present New York State guidelines and to levels which might be acceptable throughout the nation. Thus far, air to water ratios of 30:1, 20:1, 15:1 and 5:1 have been investigated, and 60-95% removals of all compounds have been achieved. Once again, desired target levels must be defined before determining whether diffused aeration is a practical treatment process for Glen Cove. Presently the 50 ug/l New York State guideline may be achievable by aeration for each of the organics present at air:water ratio of 15:1, but if the guidelines were reduced to 10 ug/l, aeration by itself would be insufficient.

2. Diffused aeration, based on the test results to date, appears to be a viable treatment option for the removal of certain organic contaminants from groundwater.

3. The aeration system had no appreciable impact on contamination of the air and created no waste disposal problem.

4. Estimated capital costs of a full-scale aeration system for plant capacities from 1-5 mgd (3,785-18,925 m^3/day) range from \$198,000-\$633,000. The estimated total annual

operating cost including amortization is about $0.19-$0.28 per 1000 gallons (3.79 m^3) of treated water. This cost is based on Glen Cove's comparatively high electrical costs and may be lower in some areas.

SECTION 3

RECOMMENDATIONS

The pilot plant phase should be continued to establish proper design data and to make accurate economic evaluations from which to derive data for full-scale operations. Major research areas should be as follows:

ADSORPTION STUDIES

1. Test the resin system in both upflow and downflow modes of operation.
2. Improve the steam regeneration system to eliminate steam condensation and losses applying steam concurrently and countercurrently to flow. Investigate higher steam loadings.
3. Other solvents besides methanol should be examined and consideration given to the treatment or disposal of the condensate.
4. Determine actual electrical utilization for all equipment.
5. Install a granular activated carbon column to compare with the resin systems and determine the feasibility of regenerating granular activated carbon with steam.
6. Evaluate the resin system for its corrosive properties and the correct materials for construction.

AERATION STUDIES

7. Continue the diffused aeration testing and install and evaluate, for comparative purposes, a packed column aeration system and a small cooling tower.

SECTION 4

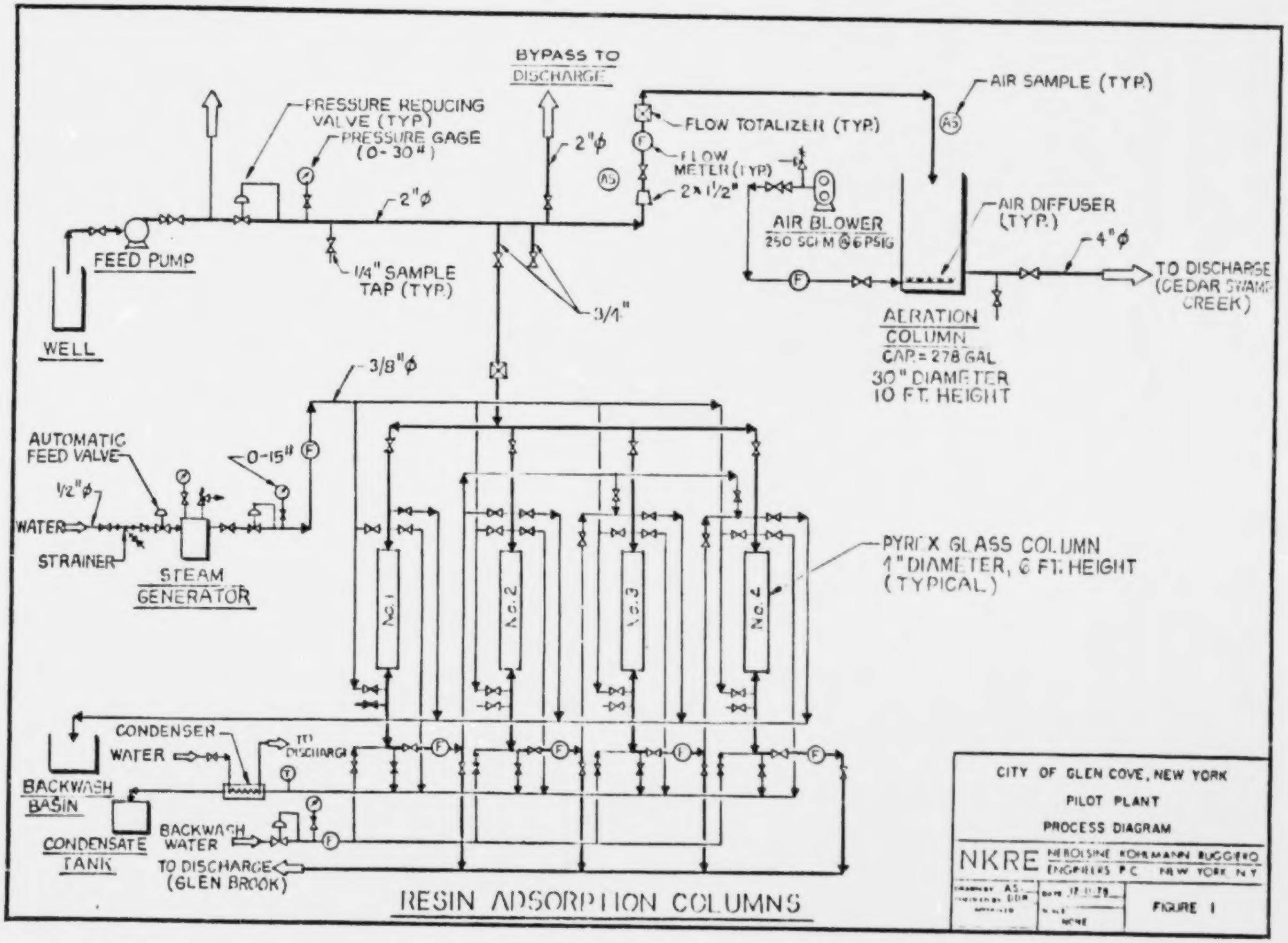
PILOT PLANT FACILITIES

Following the approval of the sub-contract with NKRE, the pilot plant was designed and the plans were reviewed with U.S. EPA (MERL-DWRD). It was decided that the systems to be tested should include diffused aeration in a countercurrent mode and adsorption using resin. A schematic flow diagram of the pilot plant facilities is presented in Figure 1.

Of the three wells at the Carney Street site, one with the highest concentration of contaminants, Well 22, was chosen for this testing program. This well draws water from an aquifer about 160 feet (49 m) below ground level. Its pump capacity is about two mgd (7570 m^3/day) and, since this is more water than is required for these tests, a major portion of the reduced well flow was discharged through a hydrant into Cedar Swamp Creek, which runs along the western edge of the Carney Street well field.

Since Well No. 22 is located at the eastern end of the well field near Highway 107, piping was installed to convey the water from the well head to the existing building which contained a portion of the pilot plant facilities. The effluent from the pilot plant facilities was conveyed to Cedar Swamp Creek. All piping had to be laid underground and under the access roads in the area because of the length of time that the pilot plant was to be operated. The installation of this piping took place during the winter, and unusually rainy weather caused delays in the installation of the pilot plant facilities. Construction of the pilot plant was completed by March 24, 1979, when operations began.

The pilot plant consisted of two separate operations or segments corresponding to the two methods being tested: resin adsorption and diffused aeration. Both systems were constructed and operated independently, using the same influent water from the well being tested. For the resin adsorption system, the water first flowed through a flow totalizer, then into a spiral wound nylon filter (which was added to the system at the end of May) and through the Pyrex glass columns containing the resin as shown in Figure 1. The columns were six feet high (1.83 m) and four inches (0.10 m) in diameter. Water flow


BYPASS TO DISCHARGE
PRESSURE REDUCING VALVE (TYP)
PRESSURE GAGE (0-30#)
2"φ
2"φ
FLOW TOTALIZER (TYP)
FLOW METER (TYP)
2 x 1 1/2"
AIR SAMPLE (TYP)
AS
AS
F
AIR BLOWER
250 SCFM @ 6 PSIG
AIR DIFFUSER (TYP.)
4"φ
TO DISCHARGE (CEDAR SWAMP CREEK)
AERATION COLUMN
CAP.= 278 GAL
30" DIAMETER
10 FT. HEIGHT
FEED PUMP
WELL
1/4" SAMPLE TAP (TYP.)
3/4"
3/8"φ
AUTOMATIC FEED VALVE
1/2"φ
WATER
STRAINER
STEAM GENERATOR
0-15#
No. 1
No. 2
No. 3
No. 4
PYREX GLASS COLUMN
1" DIAMETER, 6 FT. HEIGHT
(TYPICAL)
CONDENSER
WATER
TO DISCHARGE
T
BACKWASH BASIN
CONDENSATE TANK
BACKWASH WATER
TO DISCHARGE (GLEN BROOK)
RESIN ADSORPTION COLUMNS

CITY OF GLEN COVE, NEW YORK
PILOT PLANT
PROCESS DIAGRAM
NKRE NEBOLSINE KOHLMANN RUGGIERO ENGINEERS P.C. NEW YORK, N.Y.
DRAWN BY AS
CHECKED BY DDR
APPROVED
DATE 12-11-79
SCALE NONE
FIGURE 1

Reproduced from best available copy.

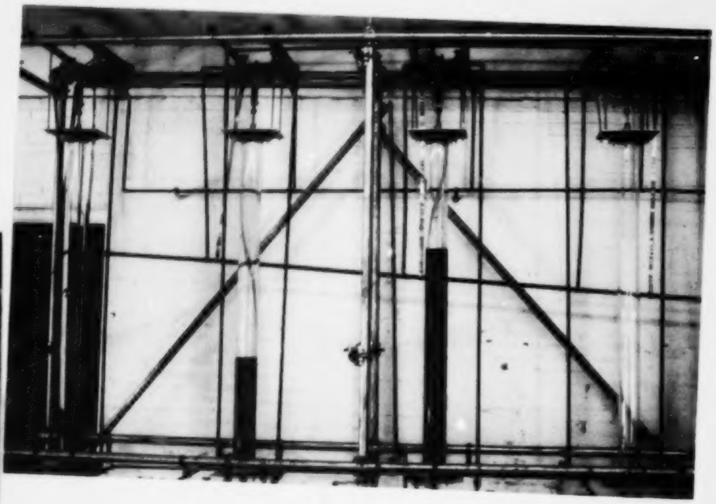
through the resin was in a downward mode. The arrangement of piping and valves allowed the columns to be operated in parallel and to be regenerated in either an upward or downward mode. In addition, City water was used to backwash the columns (rinse the resin with a counter flow of water). A Chromalox electric steam generator was provided to supply steam for periodic resin regeneration. Exhaust steam passed through a condenser on the steam discharge line, allowing the condensate to be collected.

The water to be treated by the second system, diffused aeration, flowed through an impact flow meter and a flow totalizer, both located inside the building, then to the acrylic aeration column, located outside and adjacent to the building. The test column was thirty (30) inches (0.76 m) in diameter and ten (10) feet (3.05 m) high. The influent water discharged at the top of the column and the water level was maintained at 8 feet (2.44 m) in the column. Water from the column discharged through a pipe attached about two feet (0.61 m) above ground. This effluent line was equipped with a sampling tap and a regulating valve. Effluent water from the aerator joined the effluent from the resin columns and both discharged into Cedar Swamp Creek.

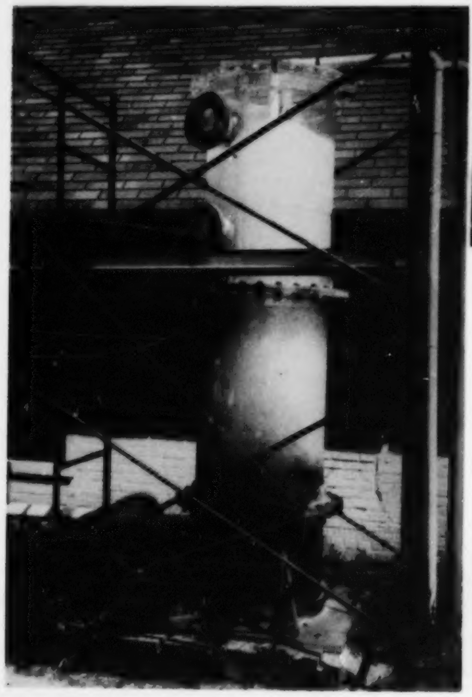
Air for the aerator was supplied by a blower, and the flow was measured by a manometer. Air was diffused at the bottom of the column by five cylindrical diffusers. This arrangement resulted in the air flowing countercurrently to the water.

Included in the equipment purchased for the pilot plant testing program was the analytical instrumentation for measurement of the contaminants, including a Tracor gas chromatograph equipped with a halogen-specific, electrical conductivity detector and a Tekmar purge-and-trap concentrator. The gas chromatograph was also equipped with an automatic integrator which determined the area of a peak and printed out the results.

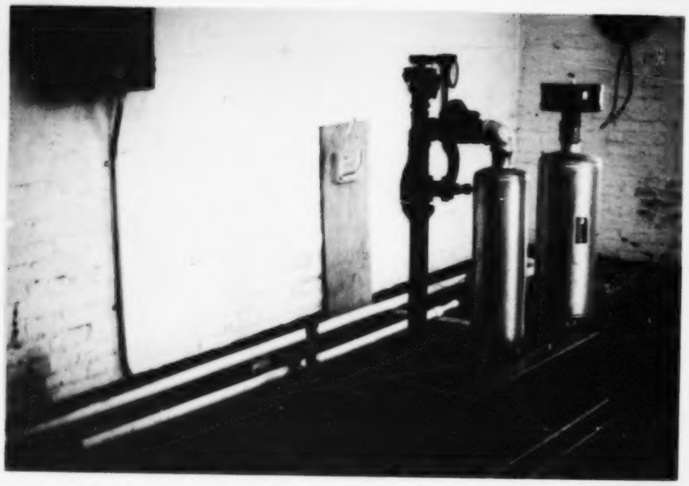
These testing units and analytical equipment are shown in the photographs presented in Figures 2 and 3.



(a) Resin Columns

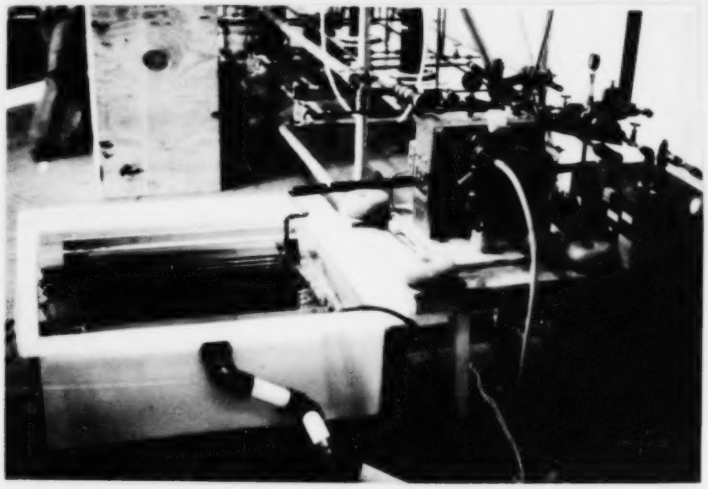


(b) Aerator column



(c) Air Pump for Aerator. On the wall is the manometer which measures the air flow.

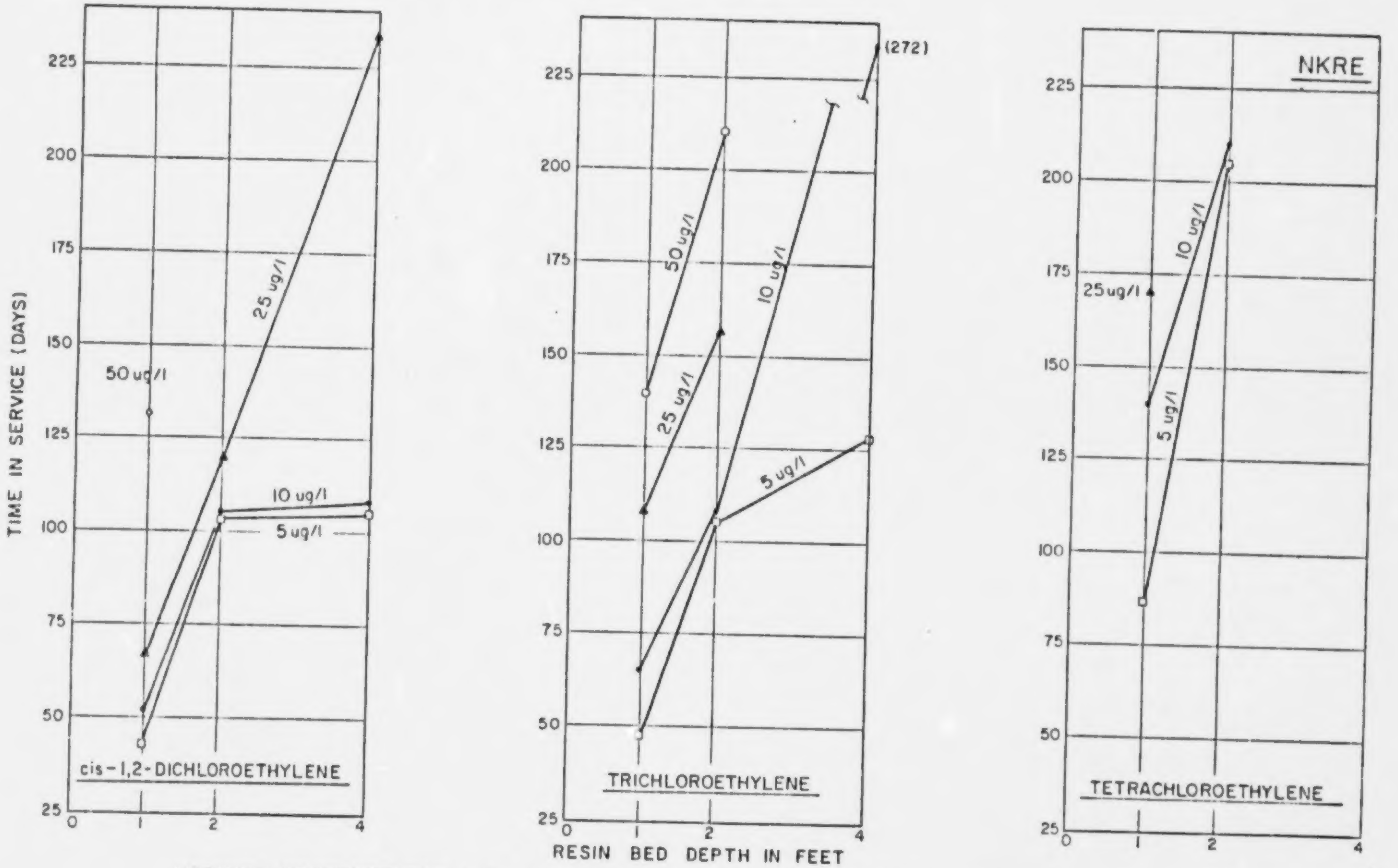
FIGURE 2



(a) Steam condenser and regenerator

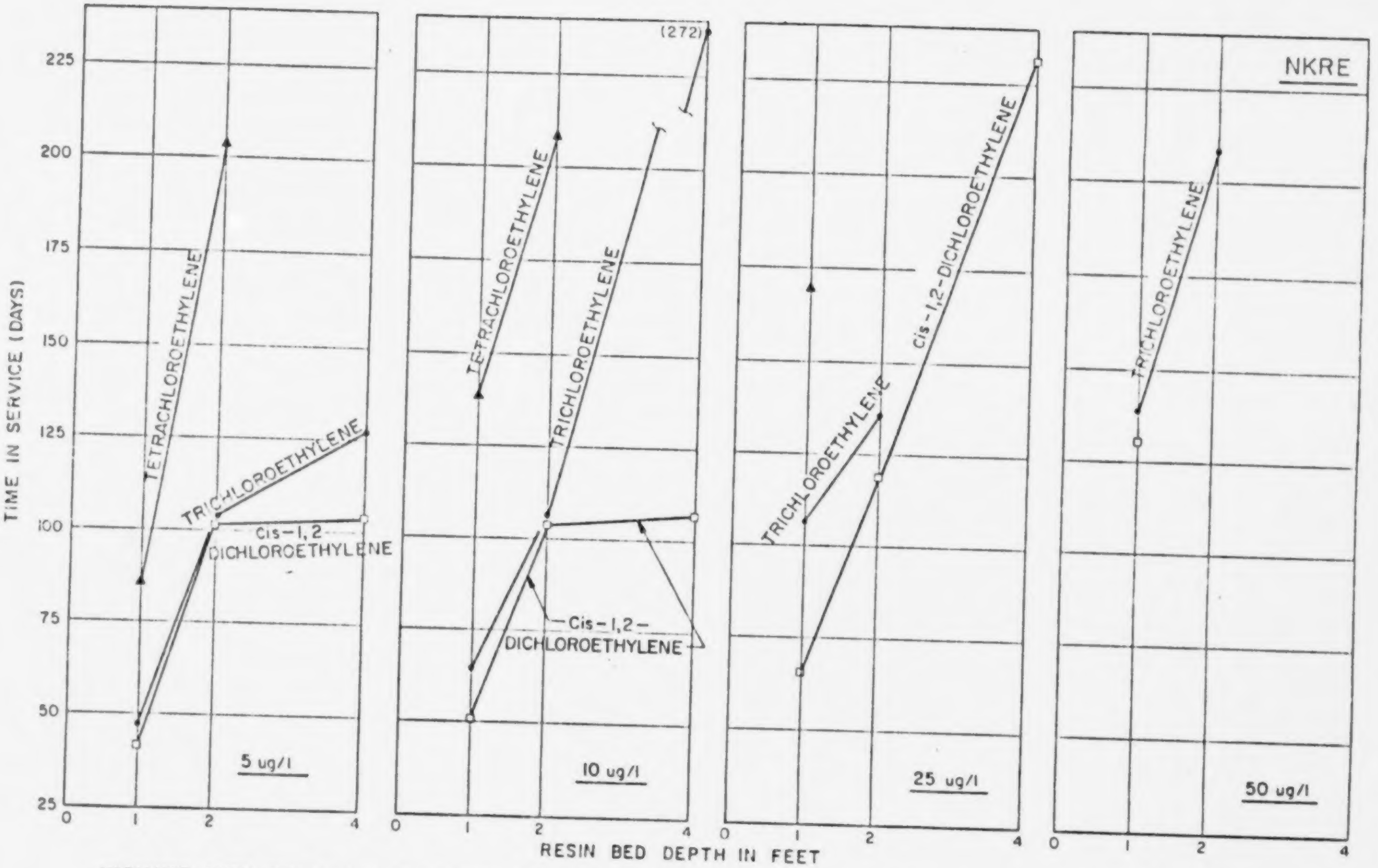
(b) Analytical instrumentation

FIGURE 3



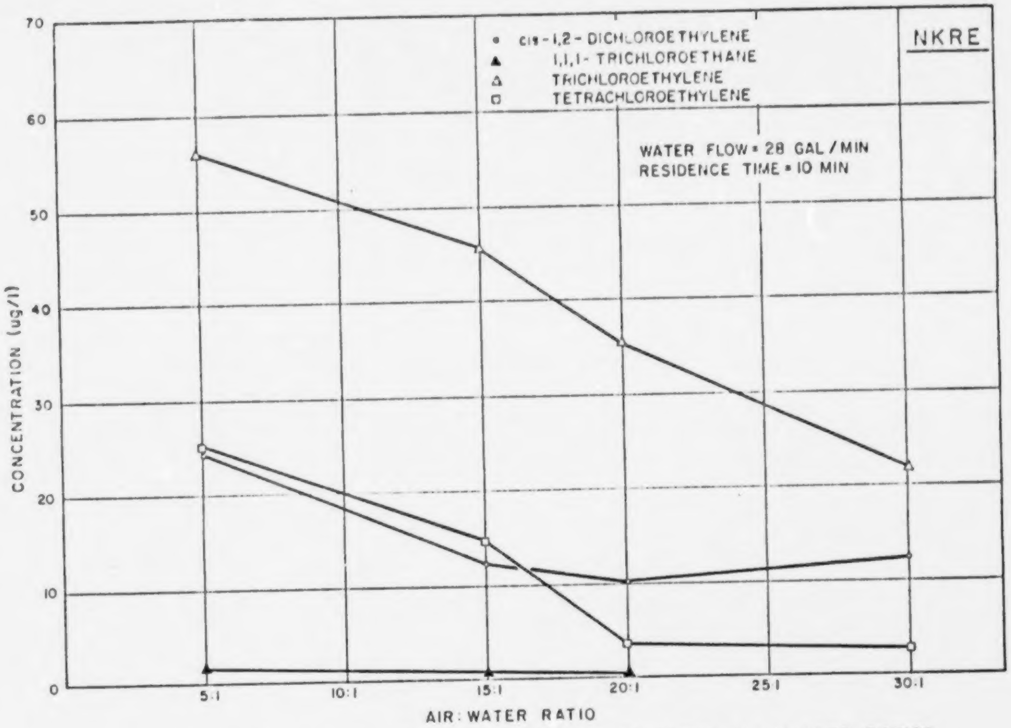
VARIANCE OF SERVICE TIME WITH BED DEPTH TO REACH SPECIFIED CONTAMINANT BREAKTHROUGH LEVELS

FIGURE 11



VARIANCE WITH BED DEPTH OF SERVICE TIME REQUIRED TO ACHIEVE BREAKTHROUGH LEVELS OF THE CONTAMINANTS

FIGURE 12



AVERAGE AERATION EFFLUENT LEVELS AT SELECTED AIR : WATER RATIOS

FIGURE 17

APPENDIX B

PHASE II REPORT (EPA-600/2-82-027)

EXCERPTS

REMOVAL OF ORGANIC CONTAMINANTS FROM DRINKING WATER SUPPLY AT GLEN COVE, N.Y.

Phase II

by

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U.S. EPA Cooperative Agreement No. CR 806355-01

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SECTION 1

INTRODUCTION

The City of Glen Cove, New York, located on the north shore of Long Island and receiving its drinking waters from wells, experienced a water shortage in 1977 due to the closing of wells because of organic contamination. Approximately 25% of the water supply was closed due to the presence of trichloroethylene, tetrachloroethylene and cis-1,2-dichloroethylene above the New York State's maximum allowable limits of 50 micrograms per liter (ug/l) for any one organic contaminant and a total allowable limit of 100 ug/l for all such compounds. Faced with this reduced water supply, the City of Glen Cove was forced to purchase water from neighboring communities and it began a crash program to install new wells. Realizing that the contamination could migrate throughout the aquifer, the City initiated a search to find methods of treating the contaminated water.

Since the contamination present at Glen Cove is also a nationwide problem, the U.S. EPA was interested in the Glen Cove problem and, consequently, funded a research project under a Cooperative Agreement (CR806353-01) in 1978 to study methods for reducing the contaminants to acceptable levels.

The City of Glen Cove, with U.S. EPA concurrence, retained the consulting engineering firm of Nebolsine Kohlmann Ruggiero Engineers, P.C. (NKRE) to build, operate, monitor and maintain a pilot plant at Glen Cove's Carney Street well field, and to evaluate the results. This pilot plant, which received water from Carney Street Well No. 22, was constructed during the early part of 1979 and began operation at the end of March. The pilot plant was operated for approximately nine months ending in early January 1980 during which time two methods of treating the contaminated water were tested: diffused aeration to strip the contamination from the water using the counterflow approach, and adsorption of the contaminants by synthetic resin. The results of this testing, which are presented in report number EPA-600/2-80-198 titled "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase I", indicated that the aeration system, with the proper air to water ratios, could reduce the contaminants below current New York State maximum allowable

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levels and that the resin was capable of lowering the contaminants to below 1 microgram per liter (ug/l), producing an acceptable quality water for several months.

Results from Phase I warranted extending the test program to continue development of the technologies, with the following major objectives:

ADSORPTION STUDIES

1. Evaluate the resin system in both upflow and downflow modes of operation.
2. Improve the steam regeneration system to eliminate steam condensation and losses by applying steam concurrently and countercurrently to flow. Investigate higher steam loadings.
3. Determine the feasibility of regenerating granular activated carbon with steam.
4. Evaluate the resin system for its corrosive properties and the correct materials for construction.

AERATION STUDIES

Continue the diffused aeration testing and install and evaluate, for comparative purposes, a packed column aeration system and a small cooling tower.

Discussions with the U.S EPA's Drinking Water Research Division in Cincinnati, Ohio and with the City of Glen Cove resulted in the approval of Phase II of the study in March 1980. NKRE was again hired as the subcontractor and Phase II was conducted from May 27, 1980 to January 30, 1981. Results of the study are presented in this report.

SECTION 2

CONCLUSIONS

RESIN ADSORPTION STUDIES

1. As in Phase I, the test results using Rohm and Haas' Ambersorb XE-340 indicated that this resin was capable of reducing the levels of contaminants to very low concentrations and, in most cases, virgin or freshly regenerated resins achieved reductions of each contaminant to less than 1 ug/l. These results were achieved for the following influent ranges: cis-1,2-dichloroethylene, 28-79 ug/l; 1,1,1-trichloroethane, 3-7 ug/l; trichloroethylene, 117-277 ug/l, and tetrachloroethylene, 33-207 ug/l.

2. Again, the general order of breakthrough was cis-1,2-dichloroethylene, trichloroethylene, then tetrachloroethylene at an application rate of 4 gpm/ft^3 (0.42 lpm/m^3) of adsorbent corresponding to an empty bed contact time of 1.9 minutes.

3. The best mode of operation proved to be countercurrent with downward flow application and upward steam regeneration.

4. The ability of the resin to be regenerated with steam, achieving better than 90 percent of virgin adsorbent capacity, was conclusively demonstrated during this phase.

5. Steam regeneration techniques were further defined in Phase II; however, they require further development. Approximately 20 bed volumes of steam at an application rate of one bed volume per hour were required to regenerate the resin. The collection of the condensate, separation of the organic phase for disposal and recycling of the aqueous phase to the next-to-be-regenerated resin column was determined feasible as a condensate treatment approach during this phase.

6. As indicated in the Phase I report, the water quality target level is an important factor in interpretation

of the data, sizing and estimating the cost of a full-scale system and determining the operation of a system. Using the application rate of 4 gpm/ft^3 (0.42 lpm/m^3) of adsorbent, (1.9 minute empty bed contact time) and the downward flow application mode, the service time to achieve an effluent level of 20 ug/l of trichloroethylene was approximately 160 days; however, if maintaining an effluent level of 5 ug/l for trichloroethylene is desired, the service time would be reduced to 110 days.

7. Corrosion studies performed with carbon steel coupons indicated that the resin does not increase corrosivity over that caused by the water itself.

8. The estimated capital and annual operating cost for a full-scale resin installation was determined for the same plant capacities used in the Phase I report from 1-5 mgd (3,785-18,925 m^3/day). These costs were computed using three columns in series operating in the downward flow mode at 4 gpm/ft^3 (0.42 lpm/m^3) and considering steam regeneration of each column three times per year. The estimated capital costs range from $308,250 to $953,400 and the annual operating costs, including amortization, are from $0.12 to $0.22 per 1000 gallons (3.79 m^3) of treated water. This cost includes an estimated cost of handling and disposal of the contaminated steam condensate and concentrated organics.

GRANULAR ACTIVATED CARBON STUDIES

The purpose of these studies was not to evaluate the adsorptive abilities of the ICI and Calgon activated carbons tested but rather to evaluate the feasibility of regenerating activated carbon with steam. The results of the three 24-hour regeneration attempts (two on the ICI carbon and one on the Calgon carbon) showed that the regeneration of activated carbon with steam, utilizing the steam equipment and conditions designed to regenerate resin, was not successful under the conditions tested.

DIFFUSED AERATION STUDIES

1. Diffused aeration appears to be a viable treatment option for the removal of volatile organic contaminants from groundwater and this approach could be used as a pre-treatment to additional treatment if more stringent water quality is required than that achievable by diffused aeration.

2. As concluded in the Phase I report, aeration can reduce the contaminants present in the well water at Glen Cove to levels below present New York State guidelines, and to levels which might be acceptable throughout the nation. This was true greater than 98% of the time for all air to water ratios tested (5:1, 10:1 and 15:1) during Phase II and for all contaminants involved.

3. The estimated capital costs of a full-scale diffused aeration system for plant capacities from 1-5 mgd (3,785-18,925 m^3/day) range from $228,200 to $470,700. This cost includes the replacement of existing high pressure well pumps after treatment. The estimated total annual operating costs, including amortization, are about $0.19-$0.33 per 1000 gallons (3.79 m^3) of treated water. This cost is based on Glen Cove's comparatively high electrical cost of $0.09 per kWh and may be lower in other areas.

4. A minimum amount of testing at the end of the program, to determine a mass transfer coefficient, indicates that additional reduction of contaminant levels may be possible using two-stage diffused aeration.

PACKED COLUMN AERATION STUDIES

1. All statements and conclusions discussed under diffused aeration studies also apply to the packed column aeration studies.

2. The use of the packing material, purchased from Munters Corporation, in the unflooded mode produced the best results with a slight improvement over that of diffused aeration at the air to water ratios of 5 to 1 and 10 to 1; however, at an increased estimated capital and operating cost.

3. The estimated capital costs for the full-scale operation system using the same capacities as those utilized in the cost estimates for diffused aeration (1-5 mgd), and including the same items, range from $275,000 to $650,500

which is 20 to 45 percent higher than that for diffused aeration. This increased cost is due to the required packing and storage below the unflooded aeration units, which would be a requirement at most utilities using well water as a source for its supply. The estimated total annual operating cost, including amortization, is about \$0.17 to \$0.32 per 1000 gallons ($3.79\ m^3$) of treated water. These costs could be reduced if environmentally acceptable alternate methods of air introduction can be demonstrated and utilized. These estimated costs are based on the \$0.09/kWh electrical cost in the Glen Cove area.

INDUCED DRAFT COOLING TOWER STUDIES

A small demonstration model of an induced draft cooling tower supplied by Baltimore Air Coil was utilized in this testing. Utilizing an air flow meter it was determined that this unit was capable of producing air to water ratios ranging from 200:1 to 700:1 at flow application rates of 2 gpm to 4 gpm respectively. Based on testing in this range, the removal efficiency was rather low, being between 48 to 61 percent average removal for the contaminants present. The unit did not achieve present New York State guidelines for trichloroethylene and seldom met the present New York State guidelines of 100 ug/l for total organic levels. Therefore, this type of unit, by itself, is not considered feasible for treating contaminated groundwater, but may possibly serve as a pretreatment method to final treatment. However, it should be emphasized that the unit used was a demonstration unit for sales purposes and a unit designed for this specific application, or other type of cooling tower units, could possibly be suitable for the treatment of contaminated groundwater.

ADDITIONAL OBSERVATIONS

1. While performing analytical determinations on the Glen Cove water supply at the U.S. EPA's laboratories in Cincinnati, three additional contaminants were identified in the well water: 1,1-dichloroethylene, 1,1-dichloroethane and 1,2-dichloroethane. Concentrations present were 0.3 ug/l, 4.6 ug/l and 10.8 ug/l, respectively.

2. During this phase of testing there was a definite shift in the contamination levels of trichloroethylene and tetrachloroethylene. During Phase I testing, trichloroethylene was the major contaminant, averaging 205 ug/l, followed by tetrachloroethylene averaging 75 ug/l.

During the second half of Phase II a shift in contamination level took place and near the end of this phase trichloroethylene concentrations decreased to an average of 130 ug/l while tetrachloroethylene concentrations increased to an average of 200 ug/l. The reason for this water quality change is unknown. Two possible explanations for causing this change could be 1) a shift in wave front or 2) a recent dumping of contaminant may have occurred.

SECTION 3

RECOMMENDATIONS

Reviewing the data developed during Phase I and this phase of testing, it becomes apparent that an efficient system for removing organic contamination would be one using aeration followed by adsorption. This approach would allow treatment by aeration to economically reduce all contamination levels and then polish the water by adsorption, thereby further reducing effluent levels to those required by guideline/standards, reducing regeneration frequencies and extending the length of service time for the adsorption system. Because this has not been previously tested on a pilot plant scale, the pilot plant operation should be continued to evaluate this approach. During this third phase of the pilot plant other gaps in the data base should also be evaluated. Major research areas for this third phase should be as follows:

COMBINED AERATION-ADSORPTION STUDIES

1. Determination of the best and most economical mix of aeration and resin to achieve the required water quality. Testing will include various air to water ratios and hydraulic loadings on the resin systems.

ADSORPTION STUDIES-RESIN

2. Testing to determine the maximum hydraulic loading for the resin system. All testing to date has utilized 4 gpm/ft^3 (0.42 lpm/m^3) which appears conservative. Only by determining the maximum hydraulic loading can the proper economics be determined. This hydraulic loading should be evaluated on a series resin system using both raw well water and aeration treated well water as influents.

3. Continuation of developing steam regeneration technique. In particular, to optimize the amount of steam required and to develop the proper handling and disposal of the steam condensate.

DIFFUSED AERATION STUDIES

4. Evaluation of the effect of two-stage aeration to determine the level of contaminant removal achievable by aeration alone and the economic impact of this system.

SECTION 4

PILOT PLANT FACILITIES

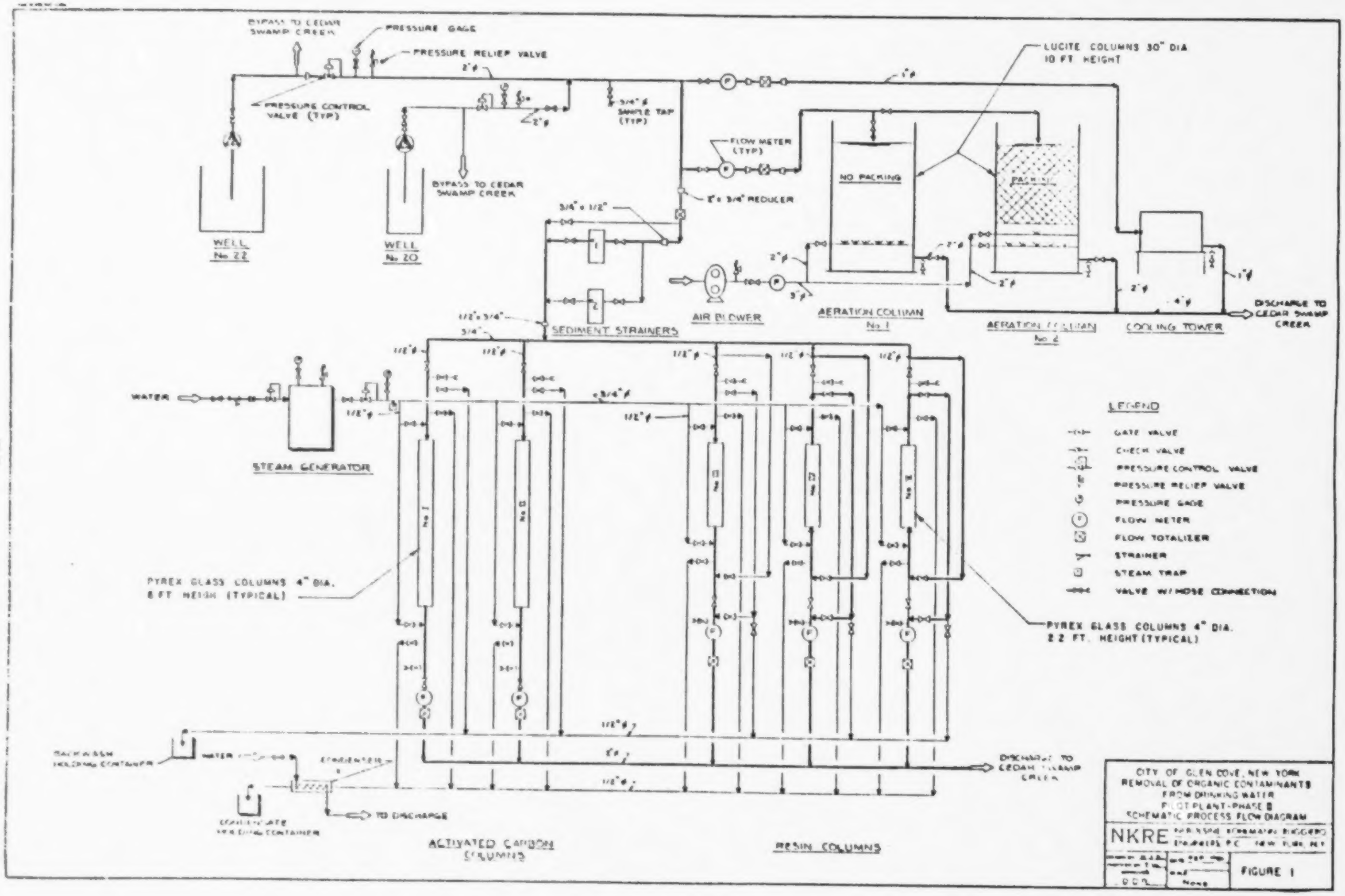
Based on the recommendations that appear in the Phase I report, various changes and modifications to the pilot plant equipment were made before Phase II began. These modifications and additions included a change in the size of columns used for the resin testing, the installation of activated carbon columns, a large steam supply, insulation and electric heating of steam piping and columns, and the installation of a packed aeration column and a small cooling tower for air stripping. It was also recommended that the smaller well in the area, Well No. 20, be connected to the system in an attempt to reduce the project electrical cost. Following the approval of the Phase II extension, the pilot plant was designed by NKRE and the plans were reviewed with U.S. EPA (MERL-DWRD).

The basic layout of the pilot plant facilities remained the same as in Phase I and the additions or modifications were made in the areas related to the particular testing. A schematic flow diagram of the Phase II pilot plant facilities is presented on Figure 1.

The same Well No. 22, having a capacity of 2 mgd (7570 m^3/day) used in Phase I testing remained connected to the system. In addition, a new pipe was installed connecting Well No. 20, having a capacity of 0.5 mgd (1900 m^3/day), in an attempt to reduce the electrical costs of the project.

The major additions and modifications to the resin testing system were made to facilitate the testing of upflow and downflow applications, countercurrent steam regeneration and to insure that pure steam was present for the regeneration of the resin.

To accomplish the desired testing on the resin system, three new columns, Nos. III, IV and V, shown on Figure I, were installed, each 4 inches (0.10 m) in diameter and 2.2 feet (0.67 m) high. This height allowed for 2 feet (0.61 m) of resin depth and ten percent freeboard. Water flow through the resin was in a downward mode for Column III and upward mode for Columns IV and V.



BYPASS TO CEDAR SWAMP CREEK
PRESSURE GAGE
PRESSURE RELIEF VALVE
PRESSURE CONTROL VALVE (TYP)
2" ϕ
3/4" ϕ SAMPLE TAP (TYP)
WELL No 22
WELL No 20
BYPASS TO CEDAR SWAMP CREEK
LUCITE COLUMNS 30" DIA 10 FT. HEIGHT
FLOW METER (TYP)
2" x 3/4" REDUCER
3/4" x 1/2"
NO PACKING
PACKING
AIR BLOWER
AERATION COLUMN No 1
AERATION COLUMN No 2
COOLING TOWER
DISCHARGE TO CEDAR SWAMP CREEK
1 1/2" x 3/4"
3/4"
SEDIMENT STRAINERS
WATER
STEAM GENERATOR
1/2" ϕ
3/4" ϕ
PYREX GLASS COLUMNS 4" DIA. 8 FT HEIGH (TYPICAL)
PYREX GLASS COLUMNS 4" DIA. 22 FT. HEIGHT (TYPICAL)
LEGEND
GATE VALVE
CHECK VALVE
PRESSURE CONTROL VALVE
PRESSURE RELIEF VALVE
PRESSURE GAGE
FLOW METER
FLOW TOTALIZER
STRAINER
STEAM TRAP
VALVE W/HOSE CONNECTION
BACKWASH HOLDING CONTAINER
WATER
CONDENSATE HOLDING CONTAINER
CONDENSER
TO DISCHARGE
DISCHARGE TO CEDAR SWAMP CREEK
ACTIVATED CARBON COLUMNS
RESIN COLUMNS
CITY OF GLEN COVE, NEW YORK
REMOVAL OF ORGANIC CONTAMINANTS
FROM DRINKING WATER
PILOT PLANT-PHASE II
SCHEMATIC PROCESS FLOW DIAGRAM
NKRE
FIGURE 1
None

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In order to insure that sufficient steam was available for regeneration, which was performed in a countercurrent direction to flow application, a higher capacity Chromalox electric steam generator was provided, capable of producing 100 lbs/hr of steam. To insure that true steam was used during regeneration, external heating devices were attached to the columns and on all piping of the steam system. The columns were heated during regeneration using removable two-feet long electrical heating mantles attached to the necessary temperature control devices. Electrical heat tracing tapes, including required temperature control devices and insulation was provided for all steam piping which included the piping from the steam generator to the column and the piping from the column to the steam condenser. Since concern was expressed that the fabricated condenser used in Phase I did not drain properly and possibly affected the amount of steam required for regeneration, a new commercial type steam condenser was purchased from American Standard Company and installed.

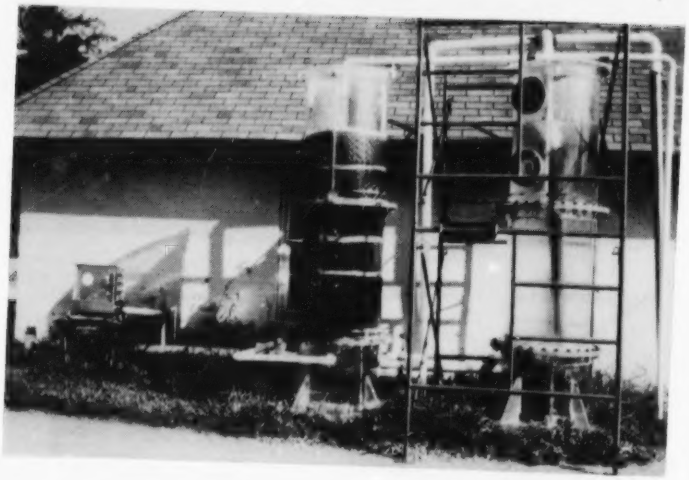
Phase II testing included the evaluation of the feasibility of regenerating granular activated carbon (GAC) with steam. To facilitate this evaluation, two six-feet high (1.83 m) columns, which were used in Phase I resin testing, were left in place and connected to the new steam system. These columns, designated No. I and II on Figure 1, were each loaded with a four foot depth of activated carbon and operated in a downward mode. Regeneration of these columns was attempted in an upward mode using electrical heating mantles to prevent the condensing of steam.

To continue the evaluation of aeration designs, a second column, identical to that used in Phase I aeration testing, was installed. Six feet of packing material purchased from Munters Corporation was placed in the column. This packing rested on a ledge two feet above the bottom of the column and air was applied below the packing either through stone diffusers or a hole in a pipe at the center of the packing. The packing was supplied in one-foot sections and was installed so that the orientation of the channels in the packing was altered from layer to layer. The space between the packing and the inside of the column was sealed at each one-foot interval to prevent air from circumventing the packing. Air to both the column used in Phase I and the new column was supplied from the same blower utilized during Phase I.

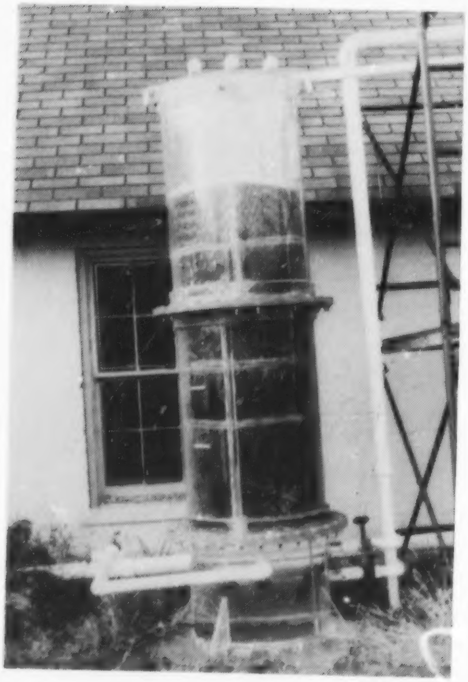
In order to evaluate the stripping efficiency of the cooling tower, a small demonstration model of an induced draft cooling tower, provided by Baltimore Air Coil, was installed. This model is based on a self-sustaining aerating system requiring no outside source of energy other than the water pressure itself.

Required analyses were performed on the gas chromatograph system purchased for Phase I with the addition of a new recorder purchased from Varian Corporation.

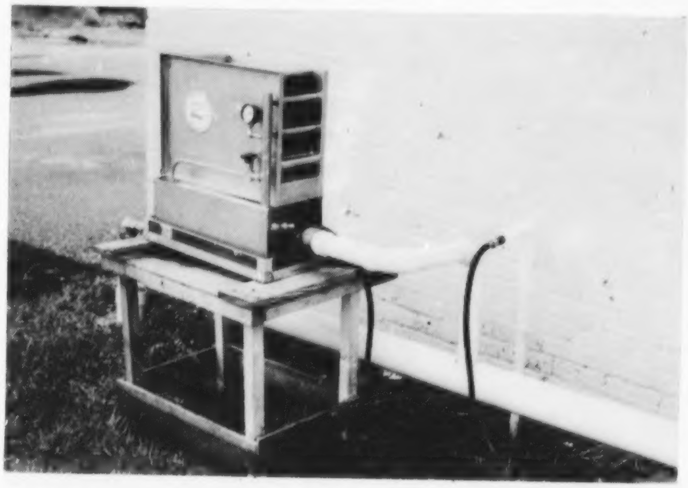
These modifications and additions to the equipment from Phase I testing are shown in the photographs presented in Figures 2 and 3.



Phase II - Aeration Testing
(Induced Draft Cooling Tower, Packed Aeration Column and Diffused Aeration Column from Phase I)

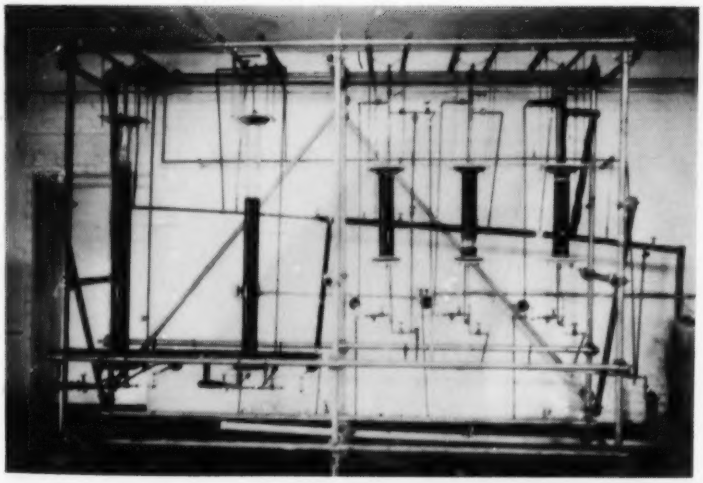


Phase II - Packed Aeration Column.

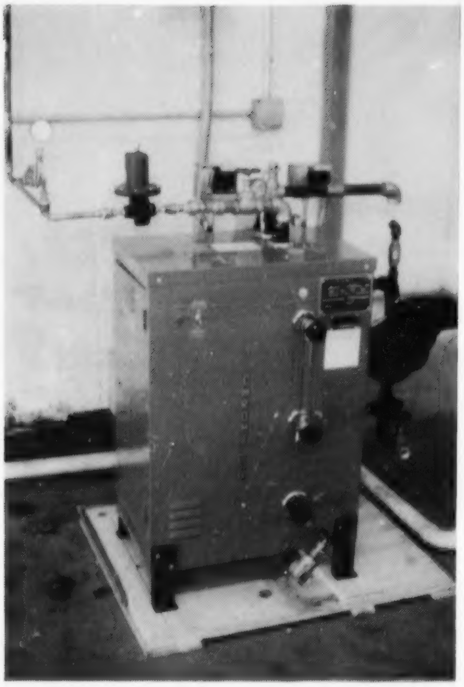


Phase II - Induced Draft Cooling Tower

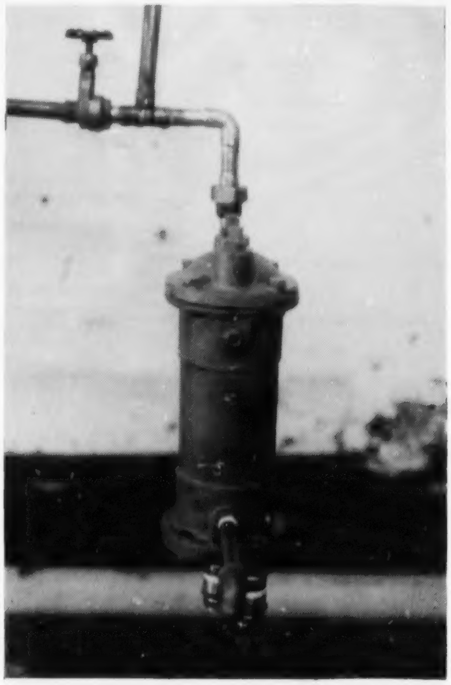
Figure 2



Phase II - Activated Carbon Columns
(larger) and Resin Columns (shorter)



Phase II - Steam Generation



Phase II - Steam Condenser

Figure 3

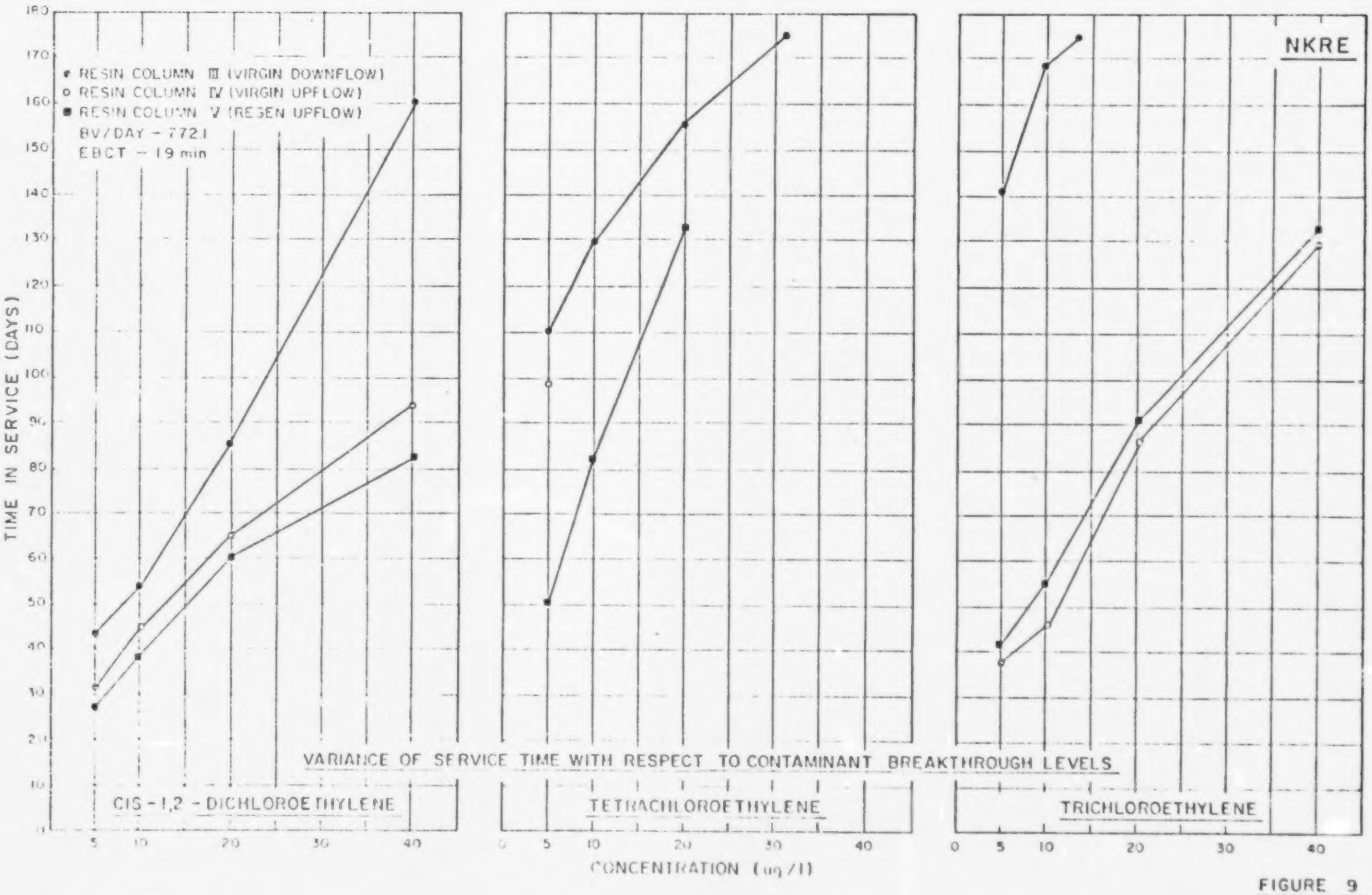
NKRE
• RESIN COLUMN III (VIRGIN DOWNFLOW)
○ RESIN COLUMN IV (VIRGIN UPFLOW)
■ RESIN COLUMN V (REGEN UPFLOW)
BV/DAY – 772.1
EBCT – 1.9 min
TIME IN SERVICE (DAYS)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
VARIANCE OF SERVICE TIME WITH RESPECT TO CONTAMINANT BREAKTHROUGH LEVELS
CIS-1,2-DICHLOROETHYLENE
TETRACHLOROETHYLENE
TRICHLOROETHYLENE
0
5
10
20
30
40
CONCENTRATION (ug/l)

FIGURE 9

TABLE 1

AERATION COLUMNS PERFORMANCE
(Average values in ug/l)

Air: Water Ratio	Contaminant	Diffused Aeration Column			Packed Column-S* (Flooded)			Packed Column-S* (Unflooded)			Packed Column-H* (Flooded)			Packed Column-H* (Unflooded)		
		Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.
5:1	cis-1,2-dichloro-ethylene	62.3	27.8	55				62.3	17.8	71				62.3	20.8	67
	Trichloro-ethylene	131.1	47.4	64				131.1	23.0	82				131.1	35.3	73
	Tetrachloro-ethylene	155.7	41.7	73				155.7	18.8	88				155.7	29.8	81
	1,1,1-trichloro-ethane	4.0	1.73	57				4.0	1.0	75				4.0	1.5	63
10:1	cis-1,2-dichloro-ethylene	43.2	13.8	68	41.1	14.6	64	54.7	13.0	76	40.7	16.0	61	54.7	15.1	72
	Trichloro-ethylene	150.2	38.8	74	152.9	35.6	77	149.0	23.4	84	152.9	41.6	73	149.0	28.6	81
	Tetrachloro-ethylene	85.0	17.8	79	75.0	10.9	85	122.0	12.8	88	74.4	13.6	82	122.0	16.7	86
	1,1,1-trichloro-ethane	3.8	1.2	68	3.8	1.1	71	4.0	0.7	82	3.7	1.3	65	4.0	0.9	77
15:1	cis-1,2-dichloro-ethylene	36.5	8.6	76	36.5	11.6	68				36.5	11.2	69			
	Trichloro-ethylene	170.8	23.3	86	170.8	31.0	82				170.8	28.9	83			
	Tetrachloro-ethylene	49.0	4.4	91	49.0	5.9	88				49.0	5.5	89			
	1,1,1-trichloro-ethane	3.7	0.7	81	3.7	1.0	73				3.7	1.0	73			

* Packed Column-S = Column packed using diffuser stones.

Packed Column-H = Column packed with air passing through a hole.

TABLE 2

COOLING TOWER PERFORMANCE
(Average Values - ug/l)

Air Water Ratio	Cis			1,1,1			Tri			Tetra			Average % Removal
	Inf.	Eff.	% Removal	Inf.	Eff.	% Removal	Inf.	Eff.	% Removal	Inf.	Eff.	% Removal	
200:1	29.6	15.3	48	3.15	1.44	54	149	68.5	54	42.6	18.7	56	53
300:1	43.1	18.0	58	3.76	1.80	52	157	67.6	57	85.9	39.0	55	56
400:1	45.7	17.1	63	4.47	1.57	65	187	75.0	60	78.0	31.4	60	62
500:1	48.9	17.8	64	3.86	1.63	58	154	62.0	60	98.4	40.5	59	60
550:1	38.3	13.8	64	3.65	1.83	50	161	58.8	63	57.9	22.0	62	60
600:1	43.5	15.6	64	3.85	1.73	55	155	61.2	61	65.9	24.9	62	61

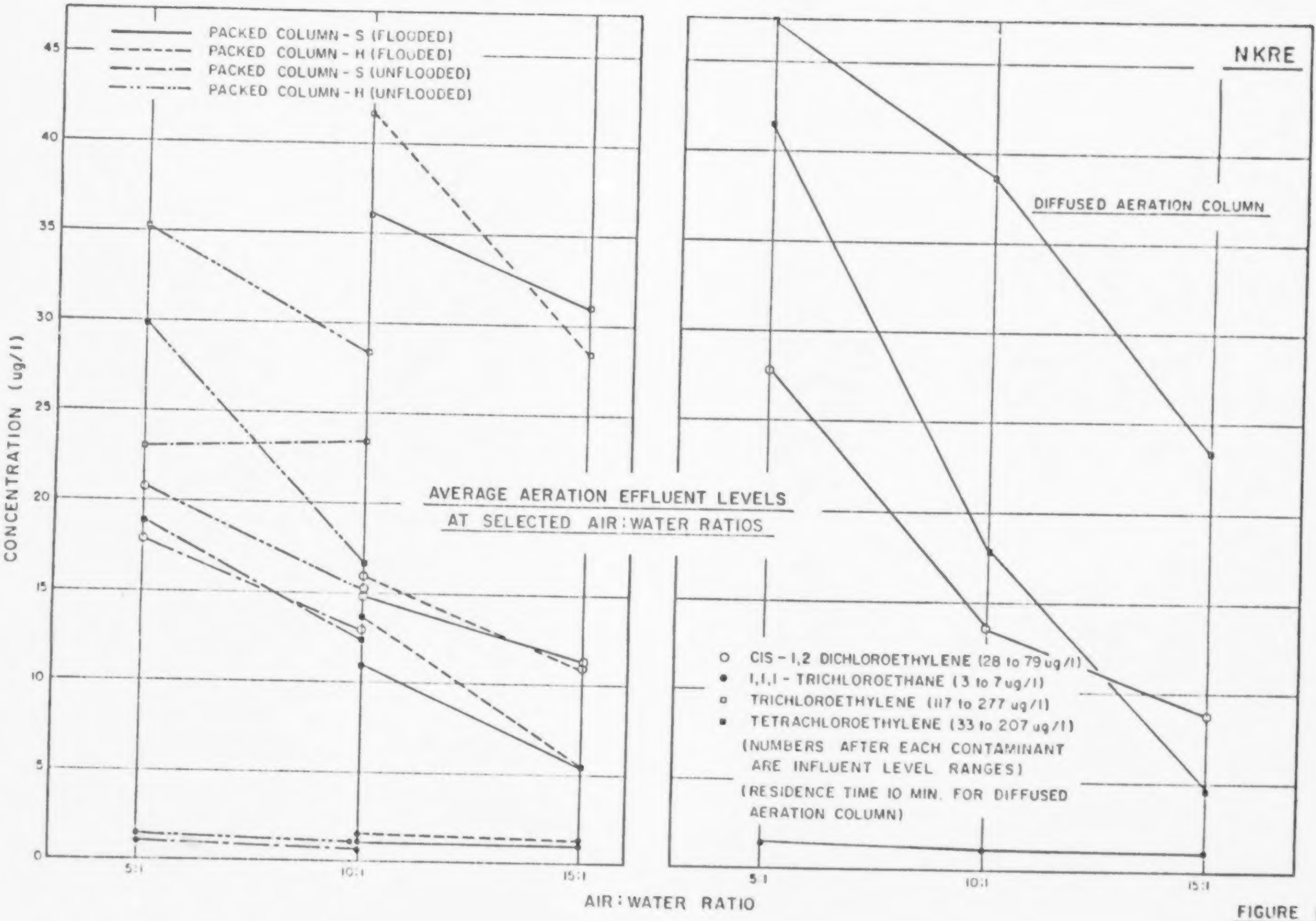
TABLE 3

AERATION COLUMNS REMOVAL EFFICIENCY
(Average Overall Percentage)

Column Type	5:1	10:1	15:1
Diffused Aeration	62	72	84
Packed-S-Flooded	-	74	78
Packed-S-Unflooded	79	83	-
Packed-H-Flooded	-	70	80
Packed-H-Unflooded	71	79	-

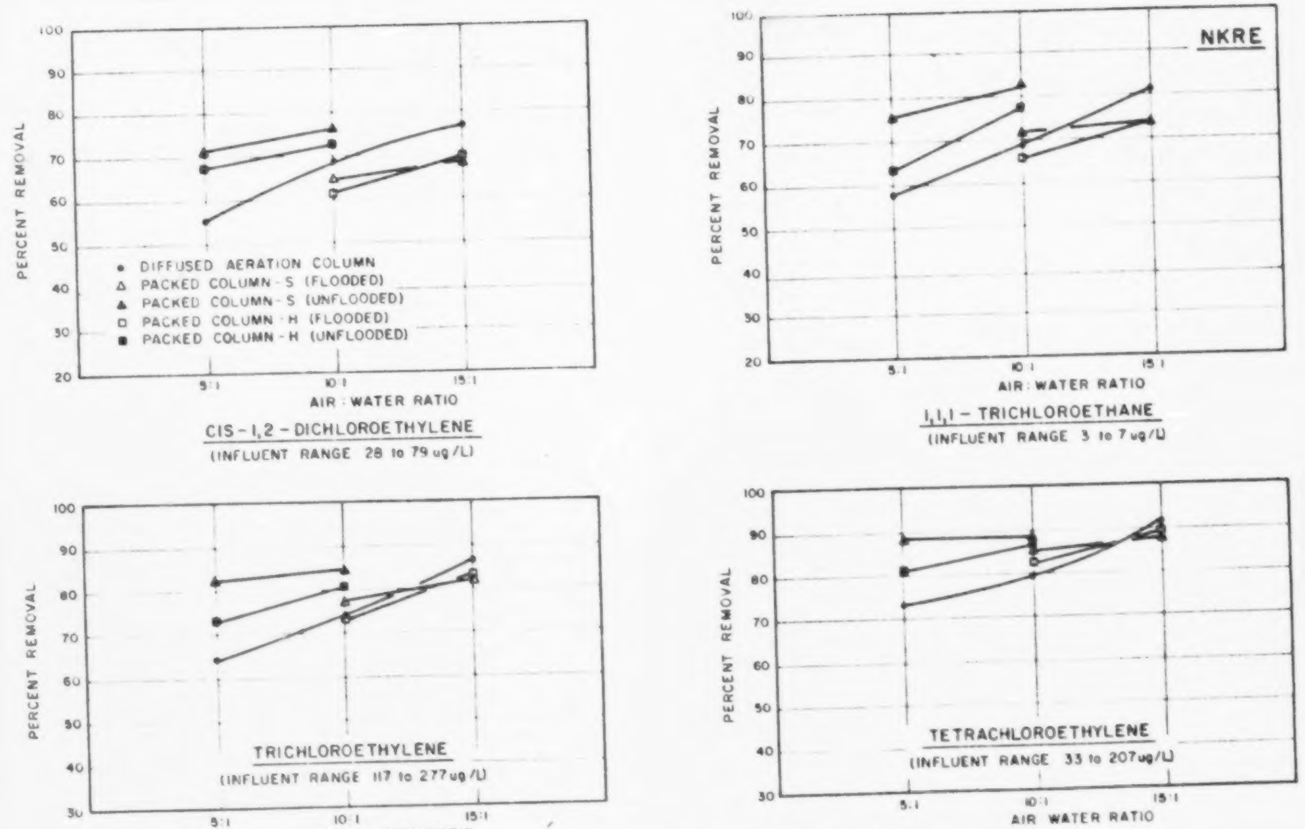
Packed Column-S = Column packed using diffuser stones.

Packed Column-H = Column packed with air passing through a hole.



AVERAGE AERATION EFFLUENT LEVELS
AT SELECTED AIR : WATER RATIOS

FIGURE 11



AVERAGE PERCENT REMOVALS AT SELECTED AIR : WATER RATIOS

FIGURE 12

TABLE 5

AERATION TESTING TO DETERMINE MASS TRANSFER COEFFICIENT

Air: Water Ratio	Source	Water Temp. (°C)	D.O. (mg/l)	Air Temp. (°C)	cis (ug/l)	1,1,1 (ug/l)	Tri (ug/l)	Tetra (ug/l)
Date:	January 28, 1981							
17:1	Inf.	13.5	7.5	8.0	100	6.3	151	219
	1st Col. Eff.	13.5	10.0		35.4	2.4	45.2	47.9
	2nd Col. Eff.	12.5	10.4		6.7	0.1	15.0	12.4
15:1	Inf.	13.5	7.2	7.5	89.3	6.2	141	207
	1st Col. Eff.	13.0	9.3		25.8	1.1	31.4	35.1
	2nd Col. Eff.	13.0	9.6		8.4	0.3	26.0	21.3
10:1	Inf.	13.5	7.2	7.0	96.3	6.2	145	214
	1st Col. Eff.	13.0	9.2		23.8	0.9	29.5	28.2
	2nd Col. Eff.	13.0	9.7		8.7	0.4	11.3	9.1
5:1	Inf.	13.5	7.4	7.0	90.2	5.7	137	199
	1st Col. Eff.	14.0	8.8		26.1	0.5	34.3	34.2
	2nd Col. Eff.	14.0	9.4		19.0	0.7	22.5	19.7
Date:	January 29, 1981							
17:1	Inf.	13.5	7.4	3.0	88.5	5.7	141	207
	1st Col. Eff.	13.0	9.8		26.3	1.2	26.5	34.8
	2nd Col. Eff.	13.0	10.4		1.7	N.O.	4.1	2.0
15:1	Inf.	13.0	7.6	3.0	89.9	5.8	139	204
	1st Col. Eff.	13.0	9.4		18.7	0.7	22.4	23.2
	2nd Col. Eff.	13.5	9.8		11.5	0.0	14.7	8.1
10:1	Inf.	13.5	7.9	5.0	90.9	5.9	146	204
	1st Col. Eff.	13.5	9.4		39.8	1.4	56.3	58.8
	2nd Col. Eff.	13.5	10.1		11.5	0.4	10.0	8.7
5:1	Inf.	14.0	8.2	5.0	103	6.3	155	218
	1st Col. Eff.	13.5	9.4		33.8	1.5	44.7	46.0
	2nd Col. Eff.	13.5	10.0		20.7	1.0	20.7	19.0

AERATION MASS TRANSFER COEFFICIENT (K_La)

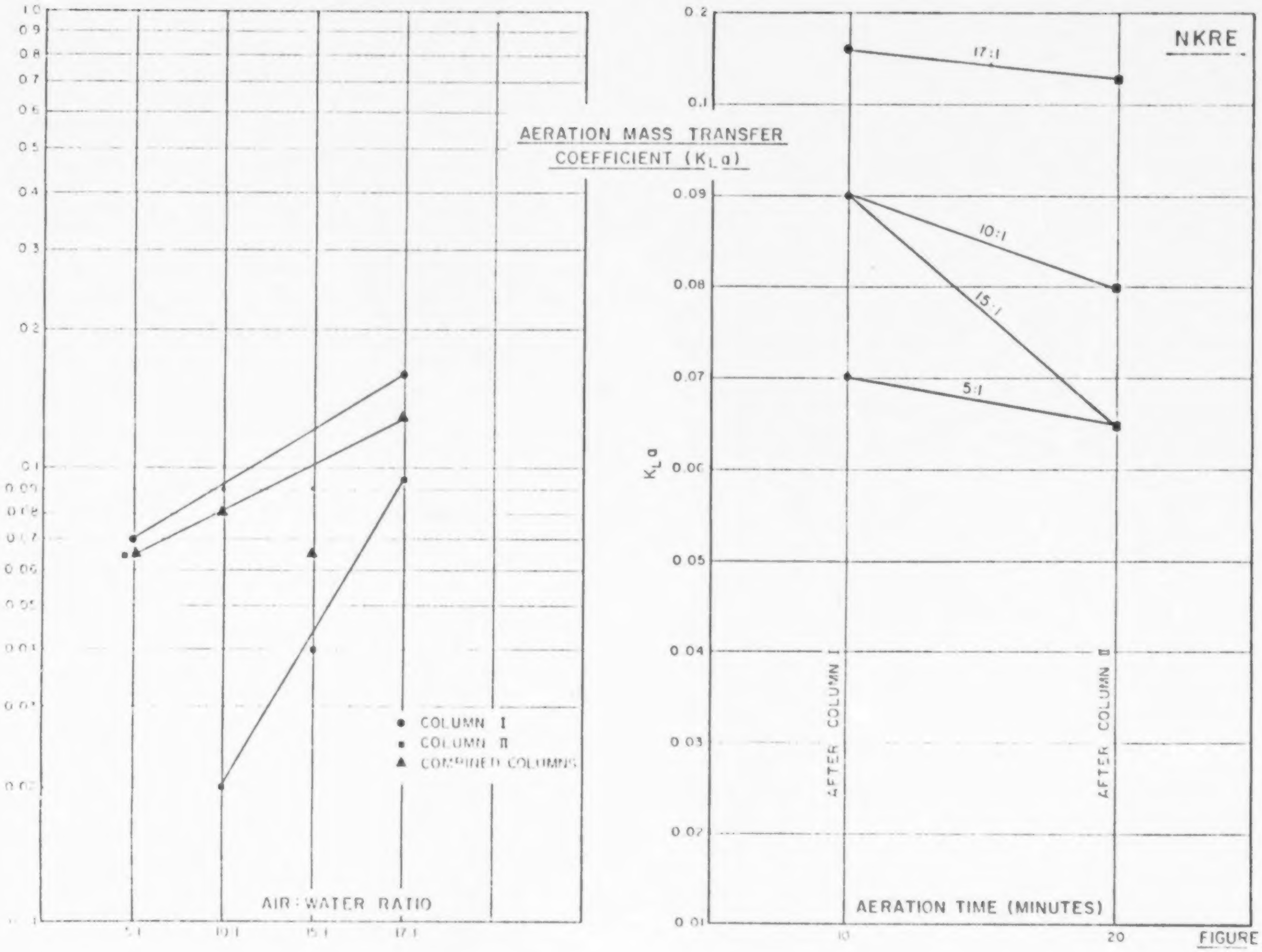


FIGURE 17

TABLE 6

ORGANIC CONTAMINANT PERCENT REMOVAL

(During KLa Testing)

COLUMN	AIR:WATER RATIO	KLa	TOTAL ORGANIC CONTAMINANT % REMOVAL
1	5:1	.07	76.0
	10:1	.09	73.6
	15:1	.09	82.1
	17:1	.16	76.2
2	5:1	.065	43.1
	10:1	.02	72.1
	15:1	.04	43.9
	17:1	.095	82.5
Combined	5:1	.065	86.5
	10:1	.08	93.3
	15:1	.065	89.9
	17:1	.13	95.5

TABLE 10

COST ESTIMATE - PACKED COLUMN DIFFUSED AERATION SYSTEM
(Based on 1983 Dollars)

	1 MGD (3785 m3/d)	2 MGD (7570 m3/d)	5 MGD (18925 m3/d)
A. CAPITAL COST			
1. Excavation	1,200	1,800	3,500
2. Concrete	51,000	85,200	110,200
3. Low Lift Well PUmp	30,000	37,000	52,500
4. Distribution Pump	15,000	16,000	40,500
5. Air Blower	47,400	64,000	126,800
6. Packing	65,000	130,000	292,000
7. Piping, Valves, etc.	22,500	28,500	58,000
8. Superstructure	83,000	83,000	103,700
9. H&V	7,000	7,000	9,500
10. Elec. & Instr.	19,000	23,700	49,800
	341,100	476,200	846,500
B. ANNUAL OPERATING COST			
1. Electricity			
0.03/kWh	15,500	29,000	59,000
0.06/kWh	31,000	59,000	117,500
0.09/kWh	47,000	88,000	176,000
0.12/kWh	62,500	117,500	235,000
0.15/kWh	78,000	146,500	293,500
2. Maintenance (3% of Equipment Cost)	6,000	8,500	18,000
3. Operators	25,000	25,000	25,000
4. Quality Control	12,000	12,000	12,000
5. Amortization			
Construction (@ 8% for 20 yrs; CFR=0.10185)	14,300	17,800	22,500
Mechanical (@ 8% for 10 yrs; CFR=0.14903)	29,900	44,900	93,200
Total Estimated Annual Cost			
0.03/kWh	102,700	137,200	229,700
0.06/kWh	118,200	167,200	288,200
0.09/kWh	134,200	196,200	346,700
0.12/kWh	149,700	225,700	405,700
0.15/kWh	165,200	254,700	464,200
Cost per 1000 gal. Treated			
0.03/kWh	0.281	0.188	0.126
0.06/kWh	0.324	0.229	0.158
0.09/kWh	0.368	0.269	0.190
0.12/kWh	0.410	0.309	0.222
0.15/kWh	0.453	0.349	0.254

APPENDIX C

PHASE III REPORT

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REMOVAL OF ORGANIC CONTAMINANTS FROM DRINKING WATER SUPPLY AT GLEN COVE, N.Y.

Phase III

by

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SECTION 1

INTRODUCTION

This third and final phase of the research study at Glen Cove, N.Y., on the removal of volatile organic compounds, namely cis-1,2-dichloroethylene, 1,1,1-trichloroethane, trichloro-ehylene, and tetrachloroethylene, from a drinking water supply was performed to further develop treatment technologies which were tested in the previous two phases and to evaluate system treatment utilizing more than one treatment technology. The results of Phases I and II indicated that both aeration methods and resin adsorption could significantly reduce the level of the volatile organics in well water.

Results from Phase II warranted extending the test program to continue development of the technologies with the following major objectives.

AERATION STUDIES

1. Continue the diffused aeration testing utilizing the same column except that the column would be covered and directed through a duct for ease of sampling.
2. Evaluate a spray aeration column utilizing induced air.
3. Evaluate the use of an air-lift pump as a method of air-stripping the volatile organics.
4. Evaluate the effect of off-gases on ambient air.

ADSORPTION STUDIES

1. Evaluate the maximum hydraulic loading for the resin system.
2. Continue the development of the steam regeneration technique.
3. Evaluate the effect of multi regenerations.

4. Determine the wave front of each particular volatile organic as it moves through a four (4) foot carbon bed.

COMBINED AERATION-ADSORPTION STUDIES

Evaluate the use of aeration followed by resin as a combined technology approach to treatment.

Discussions with the U.S. EPA's Drinking Water Research Division in Cincinnati, Ohio, and with the City of Glen Cove resulted in the approval of the Phase III extension of the study in July 1981. NKRE was again hired as the subcontractor and Phase III was conducted from October 14, 1981 to January 28, 1983. Results of the study are presented in this report.

SECTION 2

CONCLUSIONS

DIFFUSED AERATION STUDIES

1. The conclusions reached during the previous phases were confirmed during Phase III, namely that diffused aeration is a viable treatment option for the removal of volatile organic contaminants from groundwater supply, and the diffused aeration system can produce a water meeting present New York State Guidelines at air to water ratios of 15:1 or better. In addition, during Phase III it was shown that the process can be used as a pretreatment step to adsorption when extremely high water quality is required.

2. The estimated capital costs of a full-scale diffused aeration system for plant capacities from 1 to 5 mgd (3,785-18,925 m3/day) were updated during Phase III. The estimated capital costs including the replacement of existing high pressure well pumps and the installation of distribution pumps to deliver the water to consumers after treatment range from $270,000 to $563,000. The estimated total annual operating costs, including amortization, are about $0.20-$0.37 per 1000 gallons (3.79 m3) of treated water. This annual operating cost is based on an electrical cost of $0.09 per kWh which may be higher or lower in other areas.

AIR-LIFT PUMPING STUDIES

1. The operation at the Glen Cove site was not under optimum conditions for water pumping since previous studies indicated a need for a minimum air to water ratio of 10:1. This air to water ratio produces an air volume in excess of that required to deliver the design 50 gpm.

2. The system had a poor efficiency in removing volatile organics being only about 50 percent of the influent.

3. The estimated capital costs of a full-scale air-lift pump installation for capacities from 1 to 5 mgd

(3,785-18,925 m3/day) range from $274,000 to $730,000 and include the replacement of existing high pressure well pumps and required distributions pumps. The estimated total annual operating cost based on an electrical cost of $0.09 per kWh and including amortization ranges from $0.24 to $0.42 per 1000 gallons (3.79 m3) of treated water and is the highest operating cost of the systems evaluated during this phase.

INDUCED AIR SPRAY AERATION STUDIES

1. The induced air spray aeration approach requires packing or an extremely high tower to produce a desirable water quality.

2. The spray aeration studies utilizing packing produced by Munters Corporation showed that the unit is capable of reducing the overall volatile organics in the influent greater than 90 percent and produce a water quality which should be acceptable under almost any standards.

3. There was no apparent effect on the final water quality by the ambient air at the Glen Cove site. This must be determined at each site, especially in areas where air pollution is common.

4. The estimated capital costs for the full-scale induced air packed column spray aeration system for plant capacities from 1 to 5 mgd (3,785-18,925 m3/day) range from $231,000 to $629,500 including the replacement of existing high pressure well pumps. The estimated total annual operating costs, including amortization, are about $0.10 to $0.23 per 1000 gallons (3.79 m3) of treated water. It should be noted that this is based on a very low application rate of 4.5 gpm/ft2 (6.13 m3/hr). This rate was based on the maximum application rate possible during testing due to equipment and piping constraints and could possibly be much higher reducing the capital and operating costs.

PACKED COLUMN AIR-STRIPPING STUDIES

1. The test column for this approach was delivered to the Glen Cove site twice by U.S. EPA personnel who also operated the column during those test periods. This air-stripping column utilized induced ambient air and was packed with plastic saddles (supplied by Glitsch, Inc.). The removal efficiency of this approach was the

highest of all tested, exceeding 95 percent at times using the 1-inch (2.5 cm) plastic saddles.

2. As indicated for the induced air spray aeration studies there was no apparent effect on the final water quality by the ambient air quality at Glen Cove. Again this must be determined at other sites especially in areas where air pollution is common.

3. The estimated capital costs for a full-scale operation system for plant capacities from 1 to 5 mgd (3,785-18,925 m3/day) and using the design parameters determined by U.S. EPA personnel to be optimum for the Glen Cove site range from $185,500 to $489,000. This capital cost includes the cost to replace an existing high pressure well pump with a low-lift pump and the installation of distriburion pump to deliver treated water to consumers. The estimated total annual operating costs, including amortization, and based on an electrical cost of $0.09 per kWh range from $0.09 to $0.21 per 1000 gallons (3.79 m3) of treated water. This approach has the lowest estimated capital and annual operation cost of all systems evaluated during Phase III.

EFFECT OF AERATION SYSTEMS ON AMBIENT CONDITIONS

The air sampling performed by New York Testing Laboratories Inc. during this phase shows that the air quality discharging any of the aeration testing units is below any known air quality standards. After this air mixes with ambient air in the area the effect should be minimal. In addition, no liquid or solid waste are produced by the aeration treatment approaches. Therefore, aeration treatment systems should have no appreciable impact on ambient conditions.

RESIN ADSORPTION STUDIES

1. The results of the Phase III testing using Rohm and Haas' Ambersorb ® XE-340 confirmed that the order of breakthrough was cis-1,2-dichloroethylene, trichloroethylene, then tetrachloroethylene for all application rates and empty bed contact times evaluated. The results also confirmed the ability of virgin or freshly regenerated resin to reduce the level of organic contaminants below the detectable level.

2. Steam regeneration techniques were not further defined in Phase III. However, the use of the "superloading" principle, that is the collection of the condensate,

separation of the organic phase for disposal and recycling of the aqueous phase to the next-to-be-regenerated resin column, was further confirmed as a feasible method of handling the condensate produced during steam regeneration.

3. The results of evaluating a batch of poor resin supplied by the manufacturer at the beginning of Phase III resulted in the conclusion that the resin used for volatile organics removal must be of a specific particle size distribution to achieve the desired removal. This particle size distribution should be part of the specifications for any treatment plant utilizing the resin.

4. This phase evaluated the hydraulic loading and empty bed contact times to determine the optimum conditions for the resin. The results indicate that an application rate of 4 gpm/ft3 (0.42 Lpm/m3) producing an empty bed contact time of 1.9 minutes was optimum, confirming the recommendations made by the manufacturer at the beginning of the project.

5. The estimated capital and total annual costs for a full-scale resin installation for plant capacities from 1 to 5 mgd (3,785-18,925 m3/day) were updated in this report. As in Phase II the estimated capital costs were computed using three columns in series in the downward flow mode at 4 gpm/ft3 (0.42 Lpm/m3), considering steam regeneration of each column three times per year and including the estimated cost of handling and disposal of the contaminated steam condensate and concentrated organics. The estimated capital cost ranges from $432,000 to $1,446,000 and the system has an estimated total annual operating cost, including amortization, ranging from $0.18 to

   This approach has the highest estimated capital cost of all methods evaluated during Phase III, primarily due to the high cost of the resin.

COMBINED AERATION-RESIN STUDIES

The studies utilizing diffused aeration as a pretreatment step to resin adsorption indicated that the length of time between required resin regenerations was greatly increased and that the resin regeneration frequency would be about one-fifth of that required without pretreatment. However, the optimum hydraulic loading still remained at 4 gpm/ft3 (0.42 Lpm/m3) even after aeration, thereby virtually eliminating any cost savings. In essence, the estimated capital cost would be the cost of the full-scale aeration or air-stripping method used, plus the cost of the full-scale resin system. Based on the plant sizes of 1 to 5 mgd (3,785-18,925 m3/day) the estimated capital cost could range from $617,000 to $2,176,500. The estimated total annual operating cost for the resin system would be slightly reduced due to the reduced requirements for regeneration and the total system cost, including amortization, is estimated between $0.25 to $0.73 per 1000 gallons (3.79 m3) of treated water using an electrical cost of $0.09 per kWh. When comparing this cost with those of the individual systems, it is evident that the cost is very high and the combined system should only be considered if extremely high water qualities must be produced.

GRANULAR ACTIVATED CARBON STUDIES

These studies were performed to evaluate the movement of each contaminant through a granular activated carbon (GAC) bed. The results indicate that cis-1,2-dichloroethylene penetrates the GAC bed at the fastest rate, about 0.15 days per foot (30.5 cm) per ug/L, trichloroethylene ranged from 0.35 to 0.75 day per ft (30.5 cm) per ug/L, tetrachloroethylene rate ranged from 0.3 to 15.6 days per ft (30.5 cm) per ug/L and that the slowest rate of penetration was exhibited by 1,1,1-trichloroethane, traveling at the rate of 16.2 days per ft (30.5 cm) per ug/L of contaminant.

SECTION 3

PILOT PLANT FACILITIES

Based on the results and recommendations that appear in the Phase I and Phase II reports, and after consultation with the U.S. EPA's Drinking Water Research Division, various changes, additions and modifications to the pilot plant equipment were made before Phase III began. These modifications and additions included the installation of a second aeration column to be used for an evaluation of spray aeration, installation of an air-lift pump, movement of the existing blower away from the building and the addition of a blower to allow continuous operation of the diffused aeration column, the addition of several resin columns, and the modification of a column to allow sampling at one foot intervals through an activated carbon bed. Following the approval of the Phase III extension, the revised pilot plant was designed by NKRE and the plans were reviewed with the U.S. EPA Drinking Water Research Division.

The basic layout of the pilot plant facilities was altered by moving the blowers and aeration columns away from the building so that the continuous operation of the diffused aeration system would not disturb the building's inhabitants. The blowers were housed in a shed set on a concrete slab installed for that purpose. A schematic flow diagram of the Phase III pilot plant facilities is presented on Figure 1.

The same Well No. 22, having a capacity of 2 mgd (7570 m3/day), used in Phases I and II remained connected to the system as the source of contaminated water for the Phase III testing. The well pump head was reduced by removing stages so that the pump was changed from a high pressure to a low lift, thereby reducing the energy required.

Well No. 20 was converted to an air-lift pump operation to evaluate this method of aeration. This was accomplished by pulling the existing pump in Well No. 20 and replacing it with a fabricated air-lift pump. The pump utilized the air from one of the blowers of the diffused aeration system as its air supply.

To evaluate the use of spray aeration, a second column, similar to the one used for diffused aeration in Phases I and II, was installed. This column was adapted with (1) a spool piece between the base and the first section to allow ambient air to enter through the eight holes, located equidistant from each other around the perimeter of the spool piece, (2) a fan on the top to exhaust the air, thereby inducing the ambient air to enter, and (3) a transition piece between the second section and the fan. The fan assembly, purchased from Cincinnati Fan Company, consisted of a Noster Fan and one-horsepower 1750 rpm motor. The assembly is capable of delivering 2500 cfm of air. Water was supplied to the column through a distribution header, the configuration of which was varied during the test period. The column was initially operated empty but packing was added during the test period.

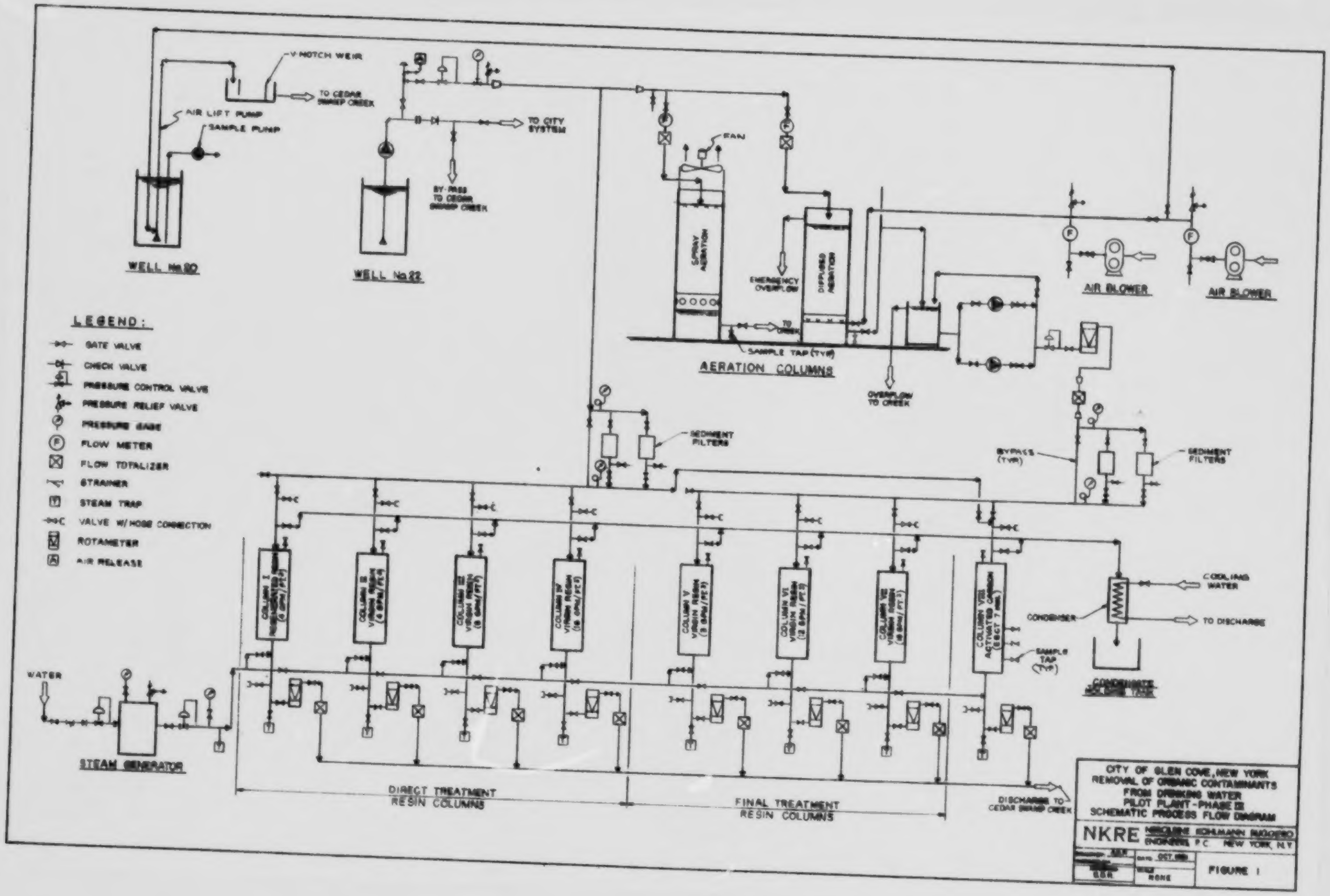
U.S. EPA personnel of the Technical Support Division in Cincinnati, Ohio, delivered and installed their packed column air stripping pilot column at the Glen Cove site twice during Phase III. This column which was designed and constructed by the Technical Support Division consists of a 24 ft (7.3 m) tall, 2 ft (0.6 m) diameter aluminum column packed with 18 ft (5.5 m) of plastic saddles purchased from Glitsch, Inc. The column has eighteen sample ports at 1 ft (0.3 m) intervals along the column height. These sample ports extend into the center of the column. A schematic diagram of this column is presented in Appendix G.

To accomplish the desired testing on the resin system, seven columns, Nos. I, II, III, IV, V, VI and VII and shown on Figure 1, were installed. Each column was 4 inches (0.10 m) in diameter and 2.2 feet (0.67 m) high. This height allowed for 2 feet (0.61 m) of resin depth and ten percent freeboard. Water flow was in a downward mode for all resin columns. All resin regeneration was performed in an upward mode using the steam system installed for Phase II.

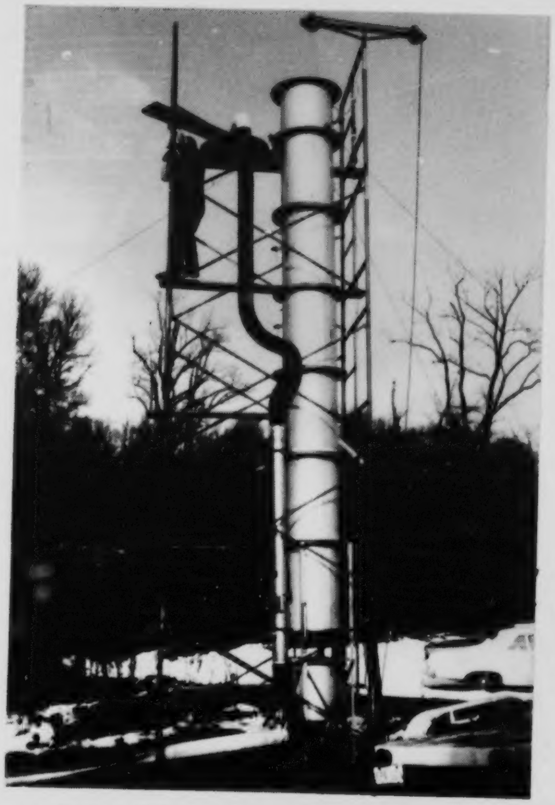
Phase III testing included the study of the movement or wave front as the various contaminants penetrate a granular activated carbon bed. To facilitate this study, one 4-inch (0.10 m) in diameter and one 6-feet (1.83 m) high column utilized in the previous phases was adapted with three sample taps, allowing for sampling at each foot (0.31 m) of media depth, and connected to the system (Figure 1, Column VIII).

Required analyses were performed on the gas chromatograph system utilized for Phases I and II.

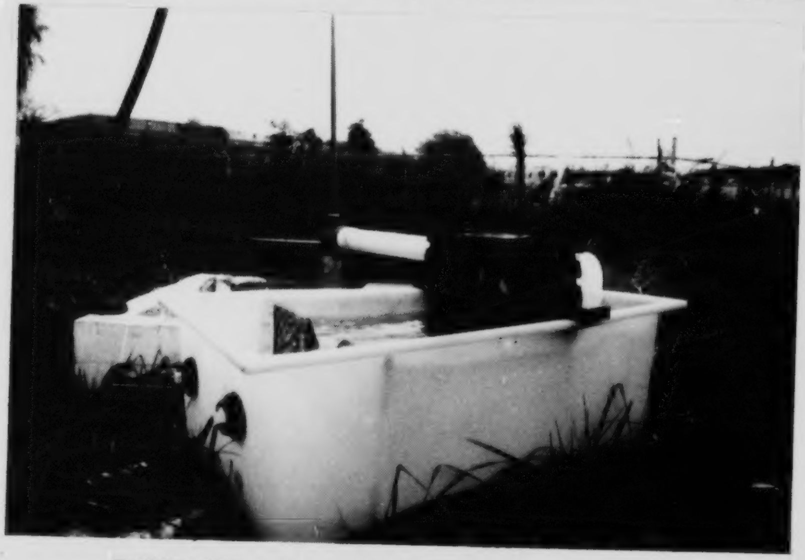
These modifications and additions to the equipment from Phase II testing are further described in Appendix A, "Phase III Work Plan" and shown in photographs presented in Figures 2 and 3.


V-NOTCH WEIR
TO CEDAR SWAMP CREEK
AIR LIFT PUMP
SAMPLE PUMP
WELL No.20
TO CITY SYSTEM
BY-PASS TO CEDAR SWAMP CREEK
WELL No.22
FAN
SPRAY AERATION
DIFFUSED AERATION
EMERGENCY OVERFLOW
TO DRAIN
SAMPLE TAP (TYP)
AERATION COLUMNS
OVERFLOW TO CREEK
AIR BLOWER
AIR BLOWER
SEDIMENT FILTERS
BYPASS (TYP)
SEDIMENT FILTERS
LEGEND:
GATE VALVE
CHECK VALVE
PRESSURE CONTROL VALVE
PRESSURE RELIEF VALVE
PRESSURE GAGE
FLOW METER
FLOW TOTALIZER
STRAINER
STEAM TRAP
VALVE W/ HOSE CONNECTION
ROTAMETER
AIR RELEASE
WATER
STEAM GENERATOR
COLUMN I REGENERATED RESIN (4 GPM/FT³)
COLUMN II VIRGIN RESIN (4 GPM/FT³)
COLUMN III VIRGIN RESIN (8 GPM/FT³)
COLUMN IV VIRGIN RESIN (16 GPM/FT³)
COLUMN V VIRGIN RESIN (3 GPM/FT³)
COLUMN VI VIRGIN RESIN (12 GPM/FT³)
COLUMN VII VIRGIN RESIN (8 GPM/FT³)
COLUMN VIII ACTIVATED CARBON (EBCT 7 min.)
COOLING WATER
CONDENSER
TO DISCHARGE
SAMPLE TAP (TYP)
CONDENSATE HOLDING TANK
DIRECT TREATMENT RESIN COLUMNS
FINAL TREATMENT RESIN COLUMNS
DISCHARGE TO CEDAR SWAMP CREEK
CITY OF GLEN COVE, NEW YORK
REMOVAL OF ORGANIC CONTAMINANTS
FROM DRINKING WATER
PILOT PLANT - PHASE III
SCHEMATIC PROCESS FLOW DIAGRAM
NKRE
NEROUNIS KOHLMANN RUGGIERO
ENGINEERS P.C. NEW YORK, N.Y.
DATE OCT. 1981
SCALE NONE
GSR
FIGURE 1

PHASE III - Diffused Aeration Column and Spray Aeration Column with Packing

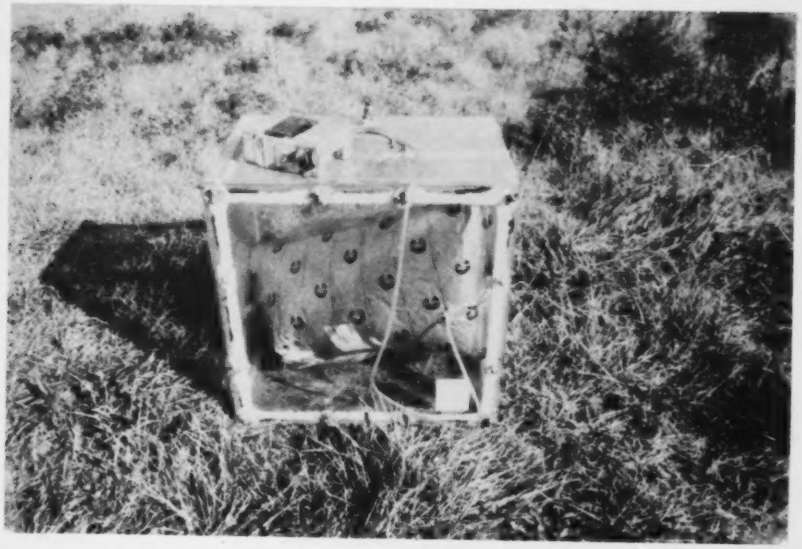


PHASE III - U.S. EPA's Packed Air-Stripping Column

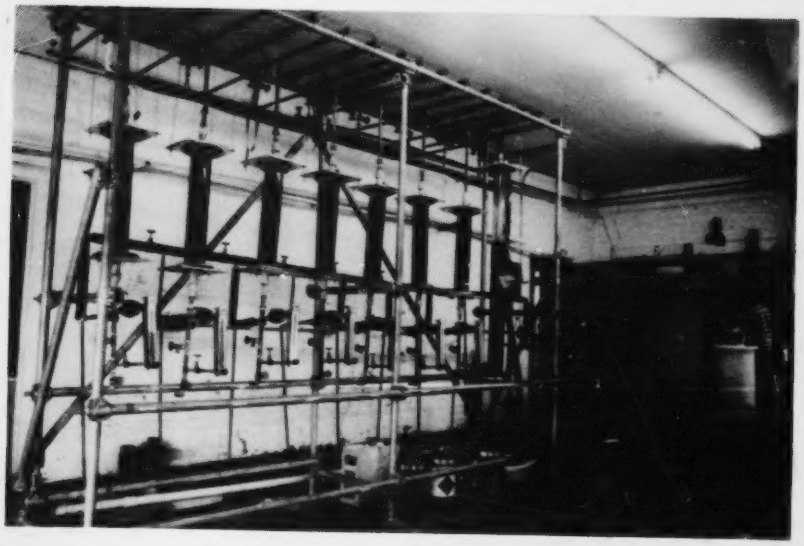


PHASE III - Air-lift Pumping System

FIGURE 2



PHASE III - Air Sampling Equipment



PHASE III - Resin Columns (shorter)
Granular Activated Column (higher)

FIGURE 3

SECTION 4

TESTING PROGRAM AND OPERATION

The objective of the testing program for Phase III was the continuation and expansion of the Phase I and II program, the results of which are presented in the reports, EPA-600/2-80-198, "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase I" and EPA-600/2-82-027, "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase II" (Project Summary EPA-600/S2-82-027). The Phase III pilot plant program continued the evaluation of air stripping and resin adsorption as methods for the removal of trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene and 1,1,1-trichloroethane from well water utilized as a drinking water supply. The objectives emphasized in Phase III were those necessary to gather the data required to evaluate the items contained in the recommendation section of the Phase II report, namely the continued evaluation of air stripping, determination of the maximum hydraulic loading for the resin, continued development of the steam regeneration technique and the evaluation of combined aeration-adsorption systems. In addition, Phase III included the evaluation of induced air spray aeration and air-lift pumping as aeration methods for organic removal.

After the Phase III extension was approved by the U.S. EPA, the necessary modifications to the existing system were made, installation of new equipment took place, and a work plan was prepared (Appendix A) and approved. The actual pilot plant operations began on October 7, 1981 when the pump in Well 22 was operated for a six-day period to achieve peak contaminant levels in the well water prior to feeding the test units. During this period, the resin in Column I, which had been regenerated several times during Phases I and II, was regenerated. The actual operation of the Phase III pilot plant was started on October 14, 1981.

As in the previous two phases the water flow through the diffused aeration column was at 28 gal/min (6.4 m3/hr), corresponding to a 10 min. residence time. The air to water ratio was varied by varying the air flow to the column. The diffused aeration column was run on a continuous basis versus the operation only on sampling days in the previous two phases. The column was covered with a plastic top and all existing air was directed through a 6-inch (0.15 m) diameter pipe to facilitate the sampling of air.

The column used for diffused packed aeration in Phase II was modified as shown in Appendix A, Figure 2, so that spray aeration utilizing induced air could be evaluated. Since the fan used to induce the air flow was a constant speed unit, producing 2500 cfm, the air to water ratio was changed by varying the water input flow. This system began operations on December 29, 1981 and initially operated with a distribution header containing five Spraying System Co. nozzles (3/4 HH-7). This system was run for approximately four months. After this period it was thought that the removals could be improved if the water were directed through the center of the column and not in contact with the column wall. In an attempt to do this the PVC distribution header used in Phase II was first installed followed by a distribution header containing one Spraying Systems Co. Nozzle (2HH-30500). After a period of about two months it was believed that there was insufficient contact time between the air and water. To increase the contact time, the original distribution with five nozzles and the Munters packing used in Phase II were installed. Two separate evaluations took place - one with 2 feet (0.61 m) of packing and the second with 4 feet (1.22 m). The column was operated only on sampling days and run for at least one hour before the water sample was collected.

The air-lift pump system, shown in Appendix A, Figure 3, was installed in Well No. 20 by Layne New York Company, Inc. The system began operation on October 20, 1981 and was basically sampled weekly throughout the pilot plant period. The air to water ratio was varied by increasing or decreasing the submergence of the air pipe in the well and varying the air applied to the well. The air lift was operated for about an hour to insure stability before the water sample was taken. The influent sample was taken from the same well using a pipe installed outside the eductor pipe of the air-lift pump system. Flow measurements of water from the pump were computed by measuring the flow over a 90-degree V-Notch weir in the system's stilling basin, shown in Figure 2.

The U.S. EPA portable air stripping column operation consisted of delivering the water from Well No. 22 through a standard fire hose to the column. The flow rate was monitored and controlled using an orifice plate, mercury manometer, and gate valve. The water was piped to the top of the column where it was distributed over the top of the packing material and cascaded down through the column. The effluent water was collected in a tank at the bottom of the column and discharged to, typically, a storm water sewer. The air was drawn up through the column using the suction side of a low pressure blower. The air flow was monitored and controlled using a damper, an inclined oil manometer, and a pitot tube. The pilot system was operated at air to water ratios ranging from 5:1 to 85:1. The air to water flow rates were such that a constant air pressure drop gradient of 0.075 inches of water per foot of column height (62 N m^{-2} n^{-1}) was maintained.

Air sampling and analysis, conducted by New York Testing Laboratories, Inc., were performed several times during Phase III and included the ambient air, the air exiting the diffused aeration column, air from the spray aeration column, air over the stilling basin of the air-lift pump system, and included sampling the air discharging the U.S. EPA column.

As in Phases I and II the resin utilized for testing was Rohm and Haas' Ambersorb® XE-340, which is designed for the removal of relatively non-polar organic molecules and hologenated aliphatics from water. Following the procedure described in the Phase I report the resin utilized in testing was first hydrated using methanol. Column I contained two feet of regenerated resin which was utilized for testing during Phases I and II while Columns II-VII contained resin from a new batch of XE-340 supplied by Rohm and Haas. Columns I-IV received water directly from Well No. 22, while Columns V-VII received water which had been previously treated in the diffused aeration column. The flow to the columns was varied so that a maximum hydraulic loading could be evaluated. The application rates were as follows:

Column No.	Application Rates	Empty Bed Contact Time
I	4 gpm/ft3 (0.42 Lpm/m3)	1.90 minutes
II	4 gpm/ft3 (0.42 Lpm/m3)	1.90 minutes
III	8 gpm/ft3 (0.84 Lpm/m3)	0.95 minutes
IV	16 gpm/ft3 (1.68 Lpm/m3)	0.48 minutes
V	8 gpm/ft3 (0.84 Lpm/m3)	0.95 minutes
VI	12 gpm/ft3 (1.26 Lpm/m3)	0.63 minutes
VII	16 gpm/ft3 (1.68 Lpm/m3)	0.48 minutes

The system was operated in this manner for approximately five months. During this period it became evident that the new batch of resin supplied by Rohm and Haas for Phase III was not operating as expected in relation to the results obtained in Phases I and II. A resin test period followed using virgin resin remaining from the batch supplied and utilized in Phases I and II, the virgin resin supplied for Phase III and a resin from a new batch. After a short period it was evident that testing should continue using the resin from the new batch. All columns except Column I were replenished with this resin and some modifications were made to the flow application rates. The application rates were changed because it was evident from the testing to date that the higher rates were not feasible. The new application rates were as follows:

Column No.	Application Rates	Empty Bed Contact Time
I	4 gpm/ft3 (0.42 Lpm/m3)	1.9 minutes
II	4 gpm/ft3 (0.42 Lpm/m3)	1.9 minutes
III	2 gpm/ft3 (0.21 Lpm/m3)	3.8 minutes
IV	6 gpm/ft3 (0.63 Lpm/m3)	1.3 minutes
V	4 gpm/ft3 (0.42 Lpm/m3)	1.9 minutes
VI	6 gpm/ft3 (0.63 Lpm/m3)	1.2 minutes
VII	8 gpm/ft3 (0.84 Lpm/m3)	0.9 minutes

The columns operated in this mode until the end of the pilot plant test period. Sampling and analysis were performed weekly for all resin columns until the latter portion of the program when sampling was reduced to every other week. The regeneration of columns when necessary followed the procedure described in the Phase II report.

The study of the contaminant movement through a granular activated carbon bed was performed in Column VIII which contained 4 feet (1.22 m) of Calgon (Filtersorb 400) granular activated carbon. This column was placed on-line January 18, 1982, with a flow rate of 21 gph (0.08 m3/hr) in a downward direction, corresponding to an empty bed contact time of 7 minutes. Initially, only the top two points were sampled until contaminants were present at the second sample point which was 2 feet (0.61 m) below the surface of the activated carbon. At this time the third sampling point was added. This procedure was followed until all points were being sampled. Sampling and analysis were performed weekly until the latter part of the project when it was reduced to every other week.

On December 16, 1982, after more than fourteen months of operation, the pilot plant testing equipment was shut down. The testing program is further defined in the Phase III Work Plan presented in Appendix "A".

SECTION 5

RESULTS

A. AERATION STUDIES

1. General

The aeration studies of Phases I and II concluded that aeration was a viable method of removing volatile organic contaminants such as cis-1,2-dichloroethylene, 1,1,1-trichloroehtane, trichloroethylene and tetrachloroethylene from a groundwater supply. The results of both phases indicated that aeration at various air to water ratios can reduce contamination well below current New York State guidelines and to acceptable levels for most locations, and that aeration can have minimal impact on the ambient air. Based on these results and discussions with the U.S. EPA's Drinking Water Research Division it was decided to continue the evaluation of aeration systems as methods of removing volatile organics from groundwater. The methods tested during Phase III included diffused aeration, induced air spray aeration, air-lift pumping and, on two occasions, a U.S. EPA Packed Column Air Stripper. As in the previous two phases the evaluation of aeration methods was based on the removal of contaminants for several air to water ratios (volume to volume).

2. Diffused Aeration

Utilizing the same column used in Phases I and II the diffused aeration studies were continued. The main purpose of the diffused aeration system in Phase III was to pretreat the water prior to resin adsorption so that a combined system could be evaluated. To achieve this the diffused aeration system was operated continuously versus the periodic operation in the previous two phases. Since the diffused aeration system actually operated as an individual unit the results of the testing during Phase III are presented separately. Diffused aeration was evaluated using three air to water ratios 5:1, 8:1 and 15:1 during the Phase III testing. The 8:1 air to water ratio was actually intended to be 10:1, however, due to an incorrect adjustment on the air manometer, which was not discovered for a period of time, the actual setting produced an air to water ratio of 8:1. The results of the sampling, which are presented in Appendix C and summarized in Table 1 were similar to those obtained in Phases I and II. The results at the 15:1 level were lower than those obtained at that ratio in the other phases. The results are presented graphically on Figures 4 through 7.

3. Induced Air Spray Aeration

During a review of the Phase III work plan with the U.S. EPA's Drinking Water Research Division it was decided to evaluate spray aeration as a method of removing the volatile organics. Since the pilot plant equipment on hand did not allow for true spray aeration it was decided to utilize a distribution header with spray nozzles at the top of a column similar to that used for the packed column diffused aeration system and induce ambient air to enter the bottom of the column by placing a fan at the top of the column. The column was operated using several air to water ratios and configurations of distribution headers, and finally with packing in the upper portion of the column. The results for this method of air stripping are presented in Appendix C and are summarized on Table 2.

The first approach was to utilize a distribution header having five nozzles (3/4 H.H-7) manufactured by Spraying Systems Co. properly spaced to cover the entire column opening. The choice of these nozzles was based on previous studies performed at Florida International University.(5) Reviewing the results presented on Table 2 it is evident that there was little effect of a change of air to water ratio on contaminant removals, slightly greater than 60 percent overall, and no air to water ratio met the present New York State Guidelines. The results of this approach are presented graphically on Figures 8 through 11.

Based on the results of the first approach and visual observations it was concluded that the nozzles were spreading the water at such an angle that the majority of water was running down the walls of the column and not achieving the proper contact with the air. It was decided to utilize a single spray nozzle. To continue testing while the new nozzle was on order, the P.V.C. spray header fabricated for Phase II testing was installed. This header consists of a series of P.V.C. pipes with holes drilled so that the spacing between each was equal. As shown in Table 2B, this method resulted in increased contaminant removals, from 50 percent to 75 percent as the air to water ratio was increased;, however, no ratio achieved New York State Guidelines levels. The results of this method are presented graphically on Figures 12 through 15.

TABLE 1

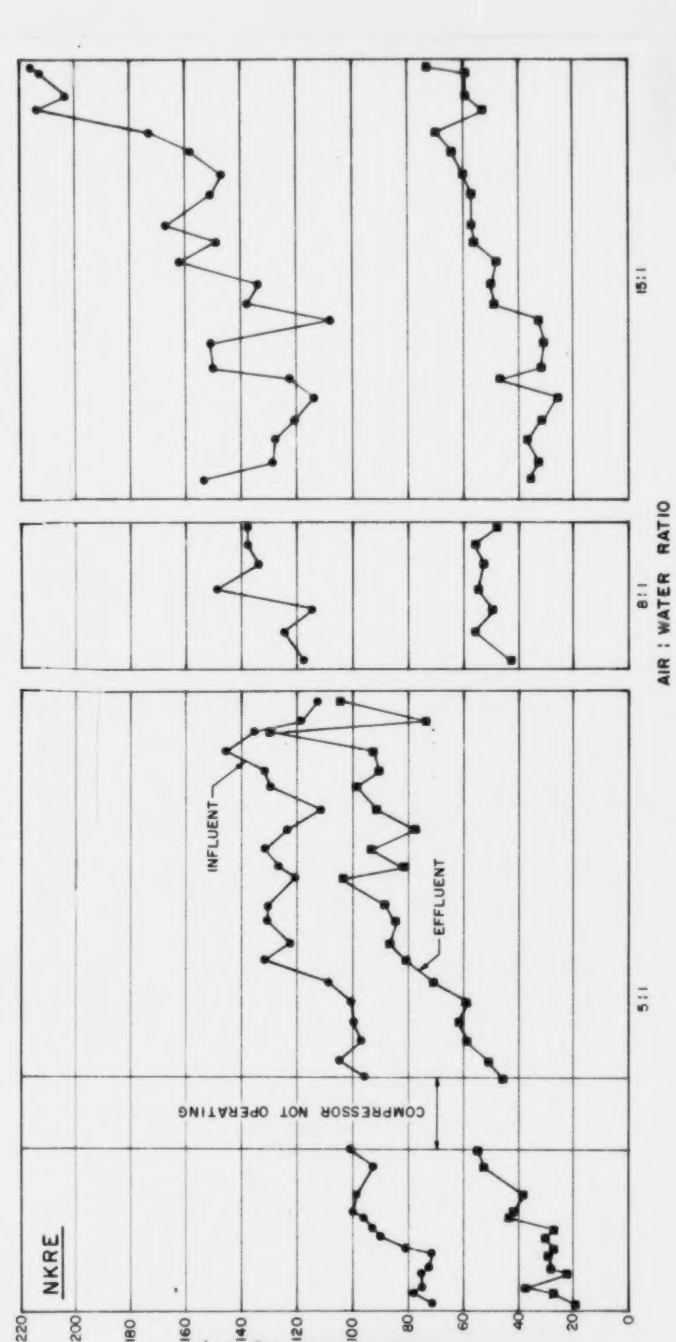
GLEN COVE, N.Y. - PHASE III

DIFFUSED AERATION SYSTEM

SUMMARY OF RESULTS

(ALL VALUES IN ug/L)

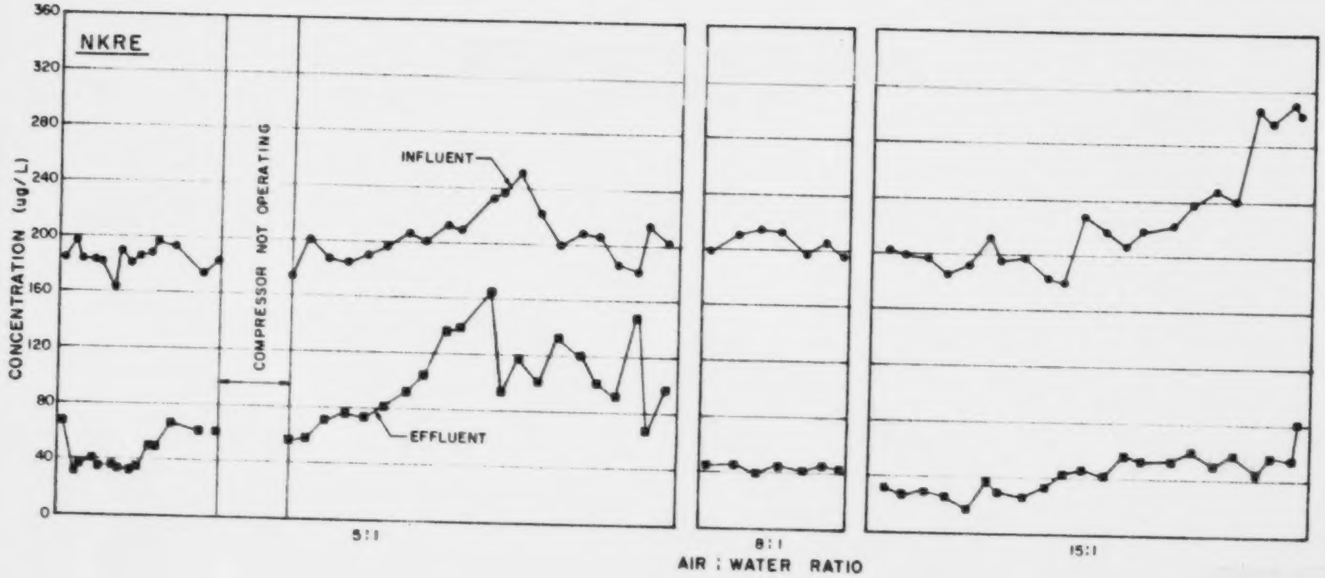
Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
5:1	cis-1,2-dichloroethylene	105.7 (71 - 146)	62.9 (19 - 131)	40.5
	trichloroethylene	194.4 (114 - 256)	78.4 (32 - 149)	59.7
	tetrachloroethylene	41.9 (34 - 51)	11.7 (0.7 - 26)	72.1
	1,1,1-trichloroethane	2.7 (201 - 3.1)	0.9 (N.N - 2.3)	66.7
8:1	cis-1,2-dichloroethylene	131.0 (113 - 149)	51.6 (43 - 56)	60.6
	trichloroethylene	206.3 (197 - 216)	44.6 (41 - 47)	78.4
	tetrachloroethylene	42.1 (35 - 50)	6.1 (5.5 - 9.0)	85.5
	1,1,1-trichloroethane	3.0 (1.7 - 35)	0.4 (0.5 - 0.7)	86.7
15:1	cis-1,2-dichloroethylene	154.7 (108 - 216)	51.8 (26 - 77)	66.5
	trichloroethylene	226.5 (180 - 309)	46.1 (18 - 80)	79.6
	tetrachloroethylene	37.3 (29 - 47)	4.4 (1.8 - 12)	88.2
	1,1,1-trichloroethane	2.6 (1.9 - 3.5)	0.7 (0.5 - 1.3)	73.1



DIFFUSED AERATION COLUMN PERFORMANCE

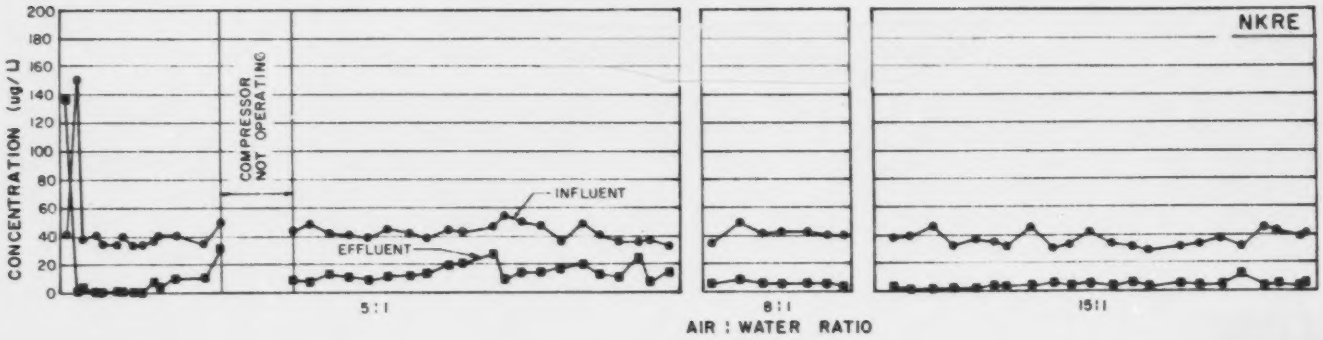
CIS-1,2- DICHLOROETHYLENE

FIGURE 4



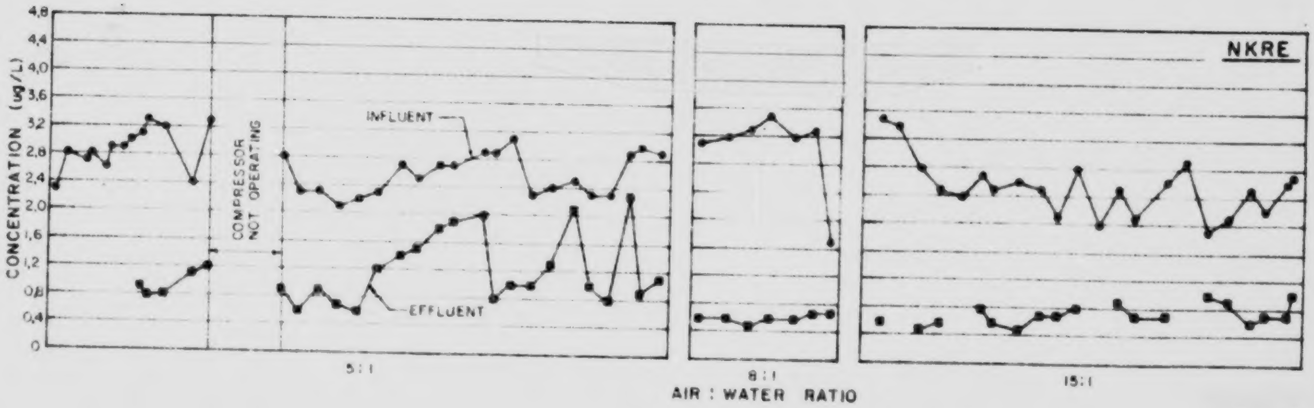
DIFFUSED AERATION COLUMN PERFORMANCE
TRICHLOROETHYLENE

FIGURE 5



DIFFUSED AERATION COLUMN PERFORMANCE
TETRACHLOROETHYLENE

FIGURE 6



DIFFUSED AERATION COLUMN PERFORMANCE
1,1,1-TRICHLOROETHANE

FIGURE 7

TABLE 2

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

SPRAY AERATION SYSTEM

SUMMARY OF RESULTS

(All Values in ug/L)

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
A.	With 5 Spraying System Co. Nozzles (3/4 HH-7)			
456:1 to 550:1	cis-1,2-dichloroethylene	112.9 (95 - 132)	36.5 (29 - 40)	67.7
	trichloroethylene	201.5 (173 - 238)	62.3 (53 - 67)	69.1
	tetrachloroethylene	45.2 (40 - 56)	13.4 (12 - 20)	70.4
	1,1,1-trichloroethane	2.3 (2.1 - 2.9)	1.1 (0.5 - 1.4)	52.2
645:1 to 935:1	cis-1,2-dichloroethylene	128.9 (119 - 146)	41.9 (37 - 47)	67.5
	trichloroethylene	210.4 (183 - 253)	70 (64 - 76)	66.7
	tetrachloroethylene	42.8 (37 - 51)	14.3 (12 - 21)	66.6
	1,1,1-trichloroethylene	2.6 (2.3 - 3.1)	0.7 (0.6 - 0.8)	73.1
1870:1*	cis-1,2-dichloroethylene	119	45	62.2
	trichloroethylene	216	79	63.4
	tetrachloroethylene	38	17	55.3
	1,1,1-trichloroethane	3.0	0.9	70.0

---

*Based on one sample

(Cont'd)

TABLE 2
GLEN COVE, N.Y. - PILOT PLANT - PHASE III
SPRAY AERATION SYSTEM
SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
Natural Draft*	cis-1,2-dichloroethylene	119	45	62.2
	trichloroethylene	216	81	62.5
	tetrachloroethylene	38	13	65.8
	1,1,1-trichloroethane	3.0	1.2	60.0
B.	With fabricated PVC distribution header			
550:1 to 935:1	cis-1,2-dichloroethylene	122.8 (113 - 135)	61.5 (60 - 66)	49.9
	trichloroethylene	214.3 (200 - 240)	107.5 (93 - 123)	49.8
	tetrachloroethylene	41.8 (34 - 50)	19.5 (16 - 24)	53.3
	1,1,1-trichloroethane	3.1 (2.9 - 3.3)	1.3 (1.0 - 1.6)	58.1
1470:1 to 5343:1	cis-1,2-dichloroethylene	125.7 (113 - 149)	59.1 (42 - 68)	53.0
	trichloroethylene	207.3 (198 - 216)	85.6 (73 - 94)	58.7
	tetrachloroethylene	41.2 (42 - 50)	15.4 (12 - 17)	62.6
	1,1,1-trichloroethane	3.2 (2.8-3.5)	1.0 (0.8-1.4)	68.8

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*Based on one sample

(Cont'd)

TABLE 2

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

SPRAY AERATION SYSTEM

SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
12,065:1*	cis-1,2-dichloroethylene	137	30	78.1
	trichloroethylene	238	62	73.9
	tetrachloroethylene	43	11	74.4
	1,1,1-trichloroethane	3.3	0.7	78.8
Natural Draft	cis-1,2-dichloroethylene	129 (115 - 149)	71.2 (65 - 77)	44.8
	trichloroethylene	207 (198 - 216)	110.5 (102 - 117)	46.6
	tetrachloroethylene	40.8 (35 - 43)	19.2 (17 - 22)	52.9
	1,1,1-trichloroethane	3.3 (3.1 - 3.5)	1.5 (1.3 - 1.6)	54.5

C. With 1 Spraying Systems Co. Nozzle (2 HH-30500)

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
445:1 to 719:1	cis-1,2-dichloroethylene	134.2 (114 - 154)	53.7 (48 - 57)	60.0
	trichloroethylene	199.8 (186 - 212)	82.9 (73 - 90)	58.5
	tetrachloroethylene	34.8 (33 - 47)	14.2 (10 - 17)	59.2
	1,1,1-trichloroethane	2.7 (1.7 - 3.5)	1.0 (0.6 - 1.4)	63.0

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*Based on one sample

(Cont'd)

TABLE 2

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

SPRAY AERATION SYSTEM

SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
3740:1	cis-1,2-dichloroethylene	130.1 (114 - 154)	55.4 (49 - 61)	74.7
	trichloroethylene	200.5 (186 - 212)	90.9 (75 - 110)	54.7
	tetrachloroethylene	43.5 (33 - 47)	16.4 (11 - 20)	62.3
	1,1,1-trichloroethane	2.8 (1.7 - 3.5)	1.2 (1.0 - 1.5)	57.1
Natural Draft*	cis-1,2-dichloroethylene	154	79	48.7
	trichloroethylene	203	130	36.0
	tetrachloroethylene	39	21	46.2
	1,1,1-trichloroethane	3.5	2.0	42.9

D. With 5 Spraying Systems Co. Nozzles (3/4 HH-7) and two feet of Munters Packing in Column

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
534:1 to 748:1	cis-1,2-dichloroethylene	141.2 (108 - 167)	23.1 (20 - 28)	83.6
	trichloroethylene	206.2 (180 - 227)	35.6 (30 - 45)	82.7
	tetrachloroethylene	33.5 (29 - 43)	5.4 (4.0 - 6.4)	83.9
	1,1,1-trichloroethane	2.4 (2.1 - 2.8)	0.7 (0.5 - 1.0)	70.8

---

*Based on one sample

(Cont'd)

TABLE 2

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

SPRAY AERATION SYSTEM

SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
1247:1 to 3740:1	cis-1,2-dichloroethylene	144.1 (108 - 167)	19.4 (17 - 26)	86.5
	trichloroethylene	206.3 (180 - 227)	32.8 (27 - 41)	84.1
	tetrachloroethylene	33.6 (29 - 43)	5.1 (3.9 - 6.6)	84.8
	1,1,1-trichloroethane	2.4 (2.0 - 2.8)	0.7 (0.5 - 1.0)	70.8

E. With 5 Spraying System Co. Nozzles (3/4 HH-7) and four feet of Munters Packing in Column

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
367:1 to 748:1	cis-1,2-dichloroethylene	189.1 (147 - 216)	13.1 (7.1 - 19)	93.1
	trichloroethylene	276.4 (237 - 309)	19.2 (14 - 29)	93.1
	tetrachloroethylene	38.9 (32 - 45)	3.0 (1.5 - 4.4)	92.3
	1,1,1-trichloroethane	2.4 (1.9 - 2.9)	0.3 (N.M.- 0.9)	87.5

(Cont'd)

TABLE 2

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

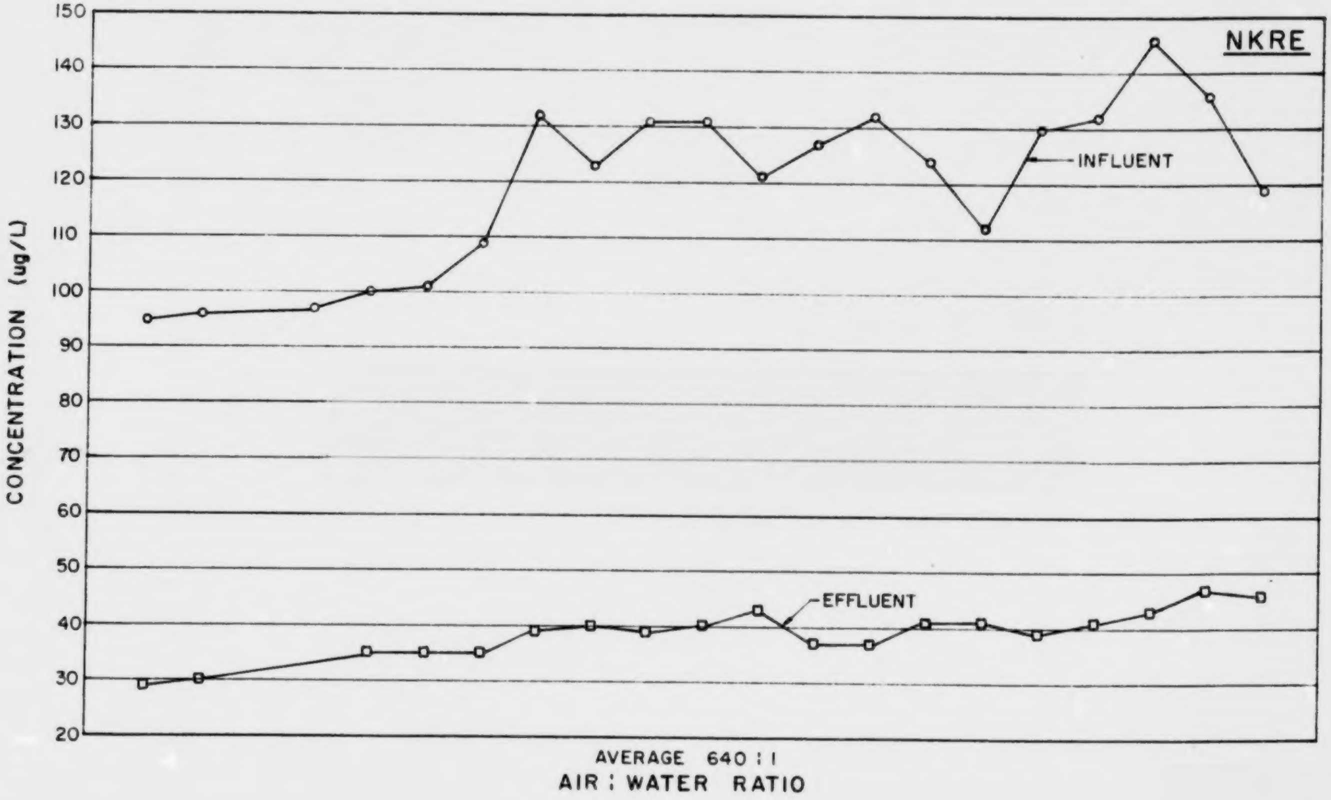
SPRAY AERATION SYSTEM

SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

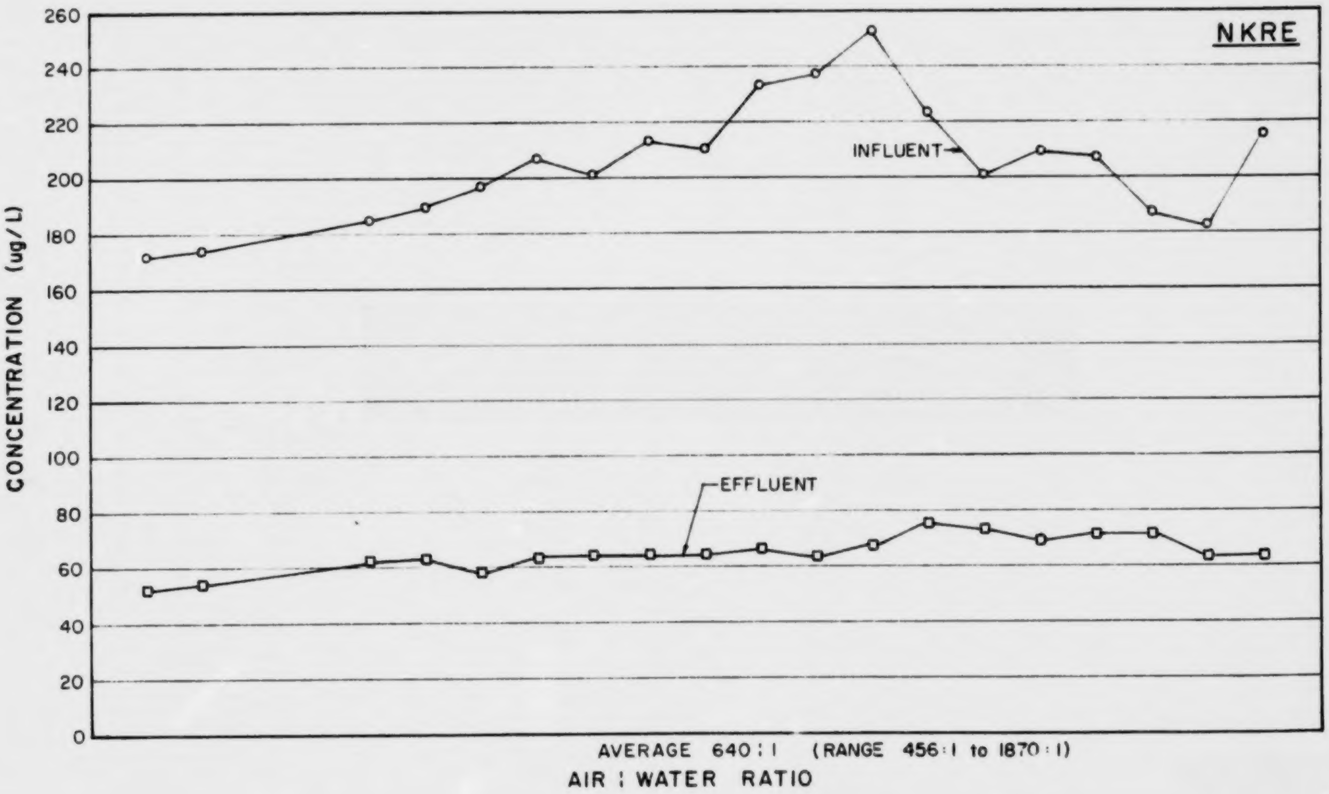
Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
1247:1 to 3740:1	cis-1,2-dichloroethylene	189.1 (147 - 216)	5.7 (3.8 - 11)	97.0
	trichloroethylene	276.4 (237 - 309)	9.7 (7.7 - 16)	96.5
	tetrachloroethylene	38.9 (32 - 45)	2.5 (1.1 - 8.1)	93.8
	1,1,1-trichloroethane	2.4 (1.9 - 2.9)	0.4 (N.M.- 0.6)	83.3
Natural Draft	cis-1,2-dichloroethylene	210.7 (203 - 216)	47.7 (29 - 75)	77.4
	trichloroethylene	302 (296 - 301)	53.3 (36 - 86)	82.4
	tetrachloroethylene	41 (39 - 43)	5.0 (3.7 - 6.7)	87.8
	1,1,1-trichloroethane	2.3 (2.2 - 2.7)	0.8 (0.5 - 1.5)	65.2



INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE
WITH 5 SPRAYING SYSTEMS CO. 3/4HH-7 NOZZLES INSTALLED

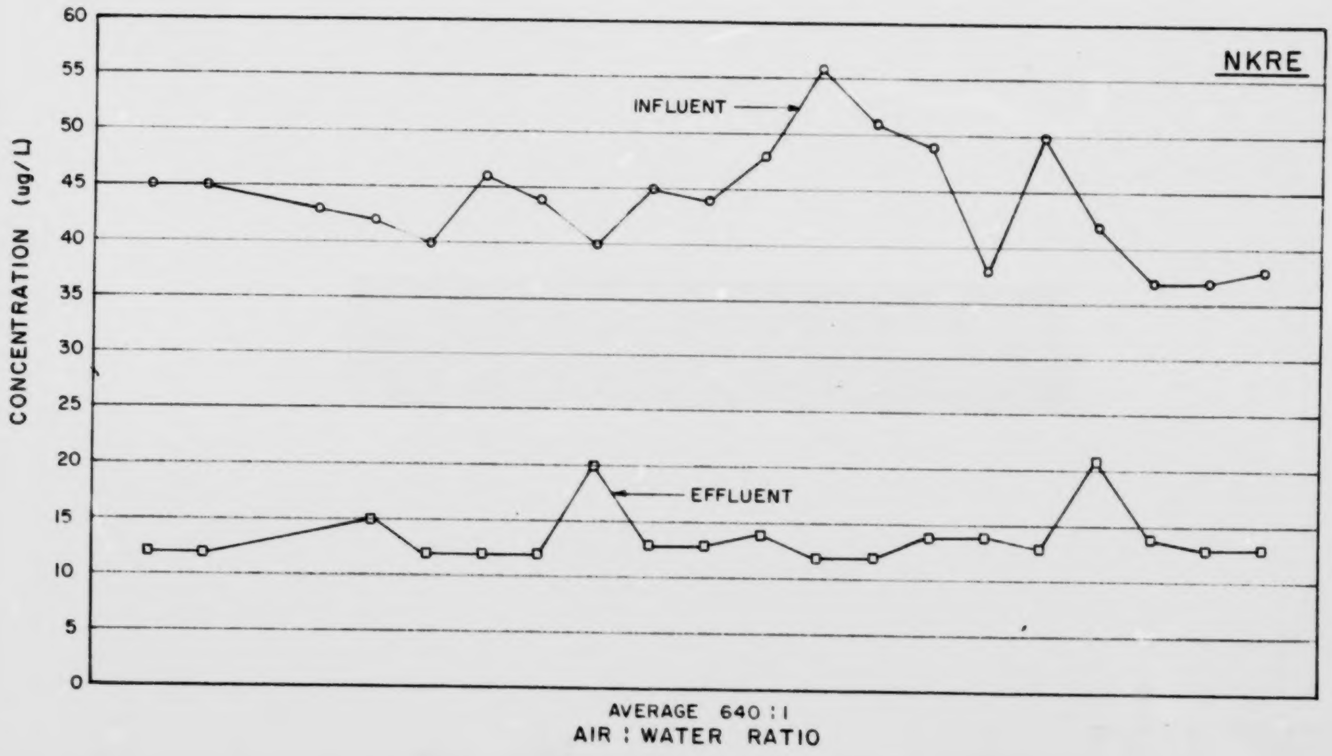
CIS-1,2-DICHLOROETHYLENE

FIGURE 8



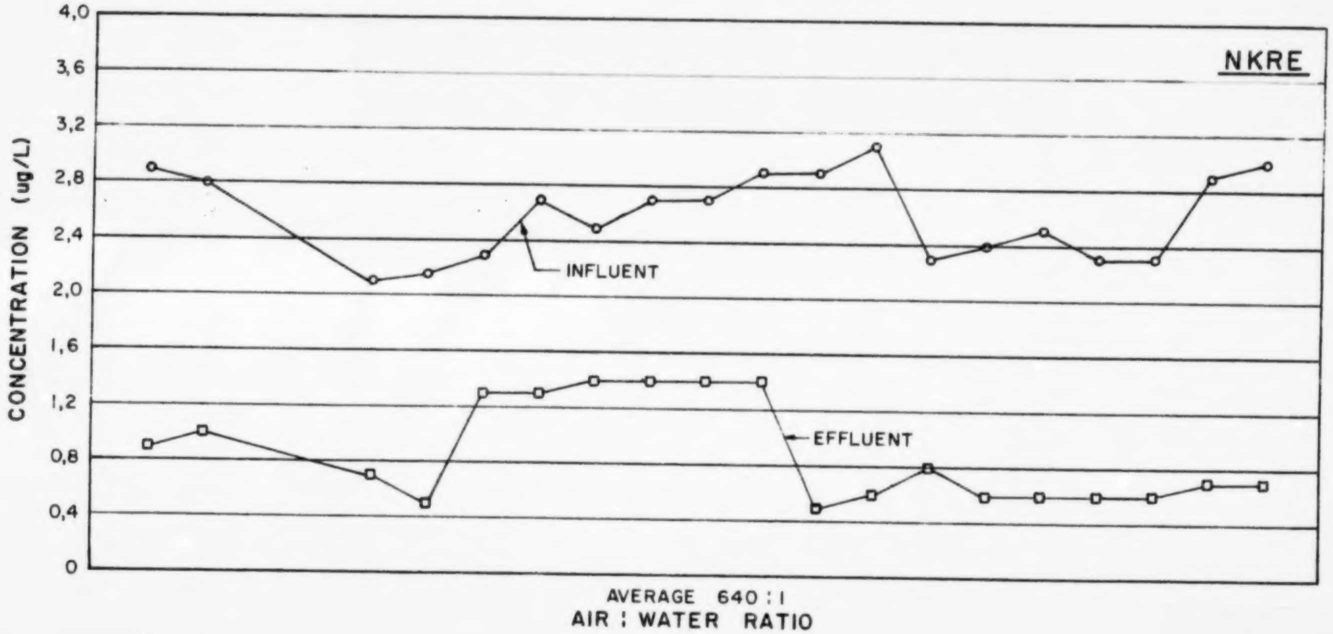
INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE
WITH 5 SPRAYING SYSTEMS CO. 3/4HH-7 NOZZLES INSTALLED
TRICHLOROETHYLENE

FIGURE 9



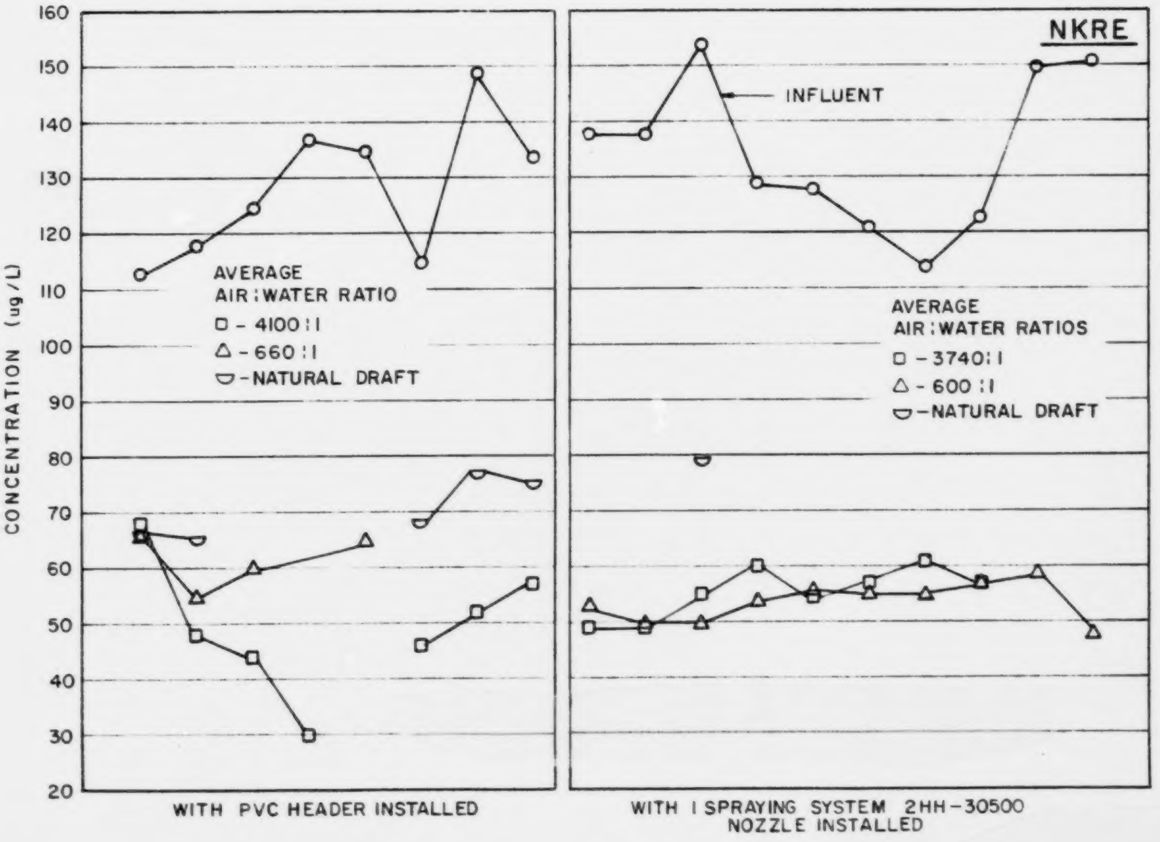
INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE
WITH 5 SPRAYING SYSTEMS CO. 3/4HH-7 NOZZLES INSTALLED
TETRACHLOROETHYLENE

FIGURE 10



INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE
WITH 5 SPRAYING SYSTEMS CO. 3/4HH-7 NOZZLES INSTALLED
1,1,1 - TRICHLOROETHANE

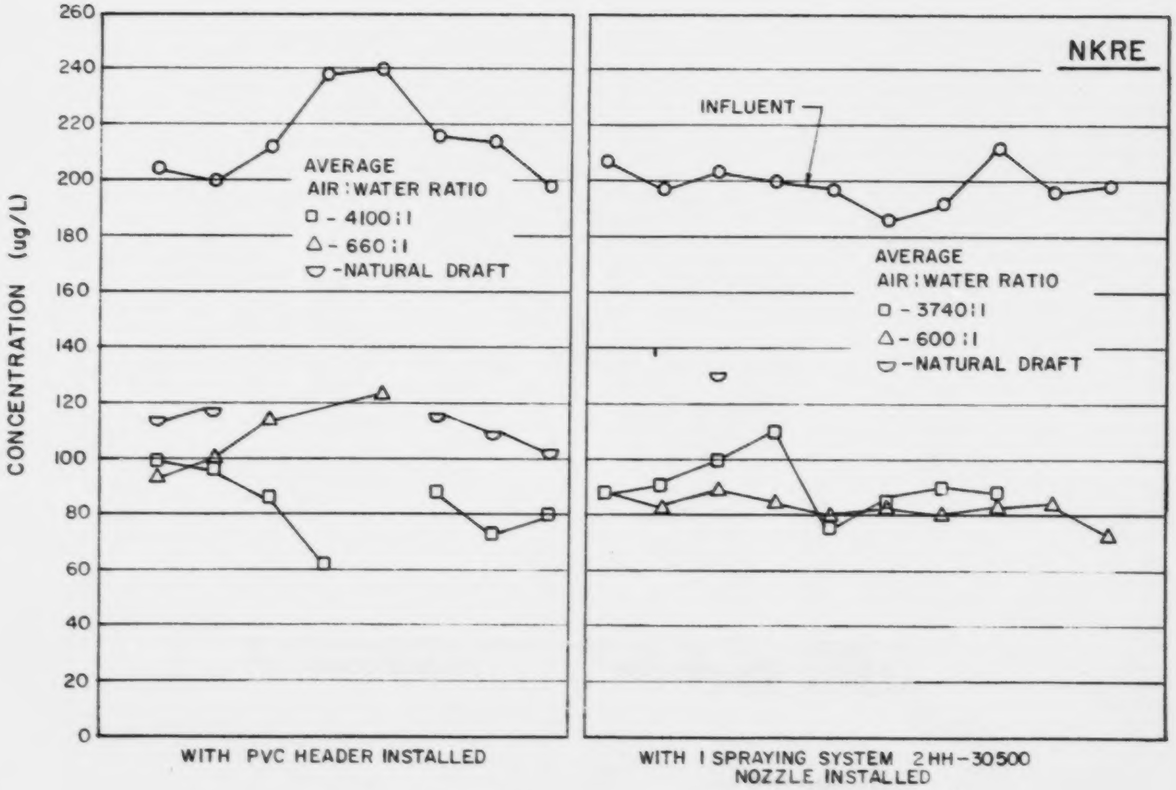
FIGURE 11



INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE

CIS-1,2-DICHLOROETHYLENE

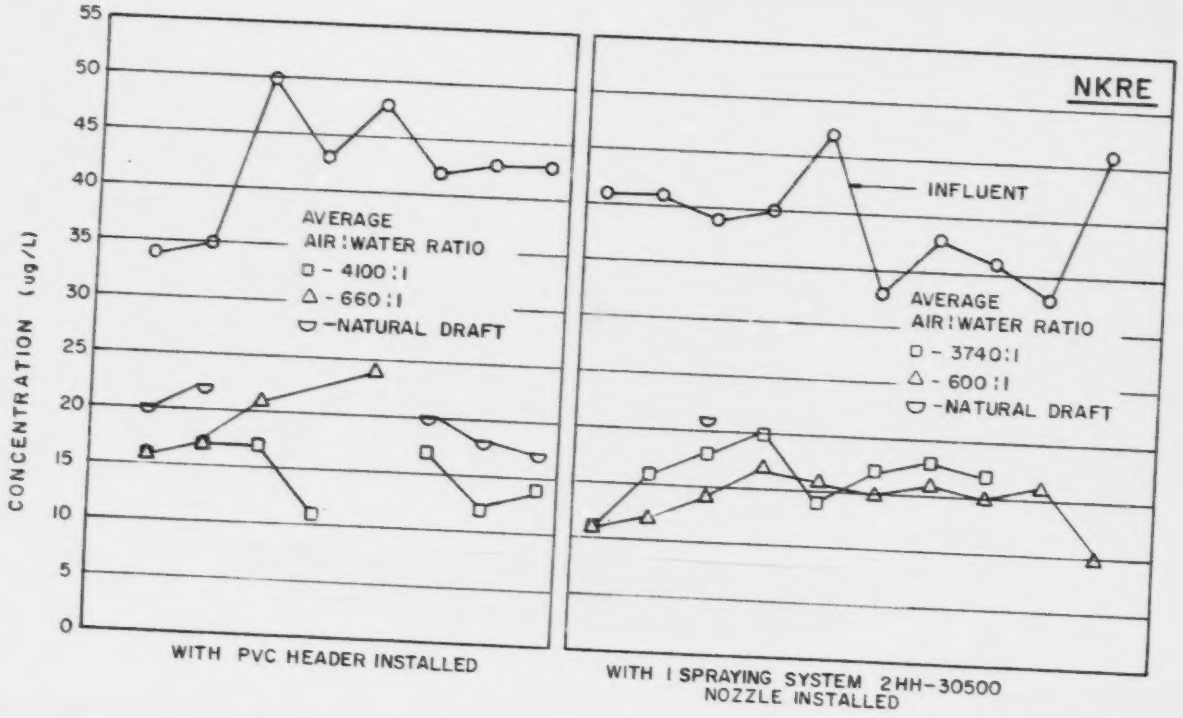
FIGURE 12



INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE

TRICHLOROETHYLENE

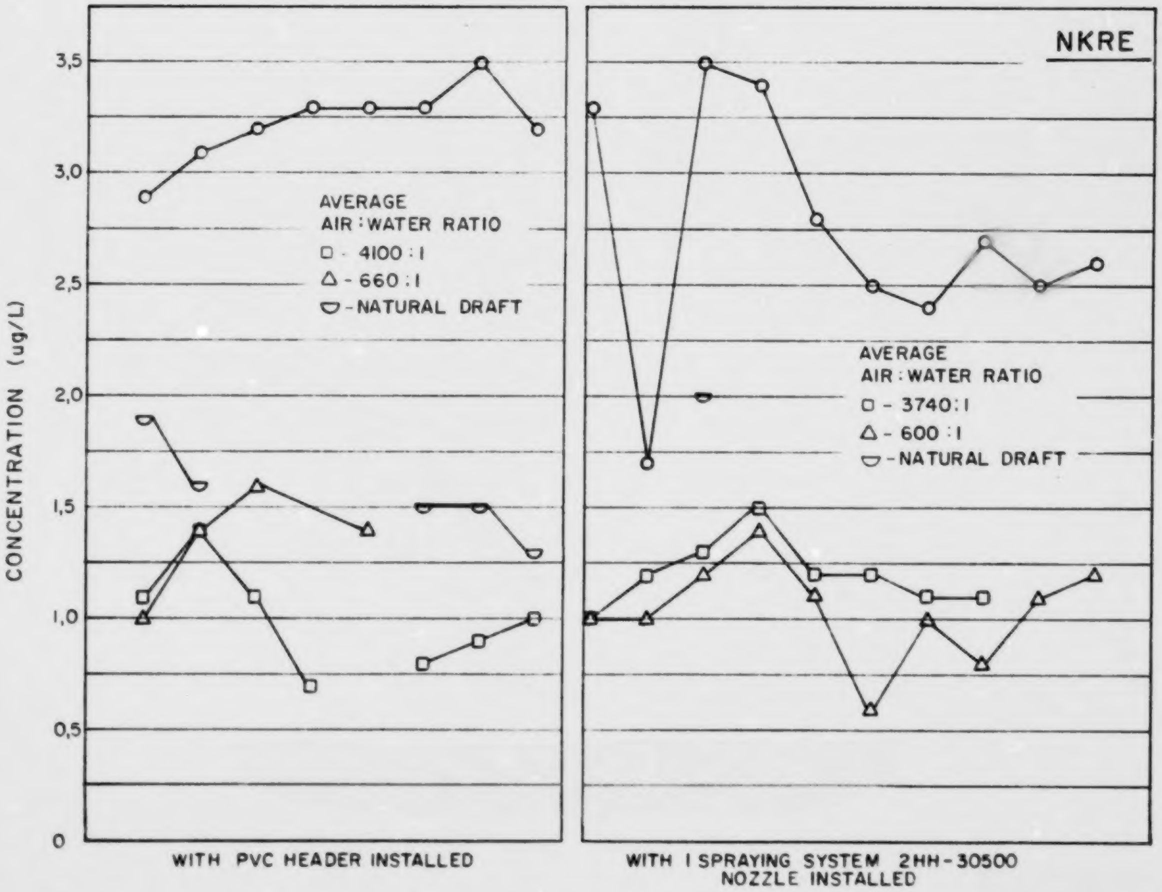
FIGURE 13



INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE

TETRACHLOROETHYLENE

FIGURE 14



INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE

1,1,1 - TRICHLOROETHANE

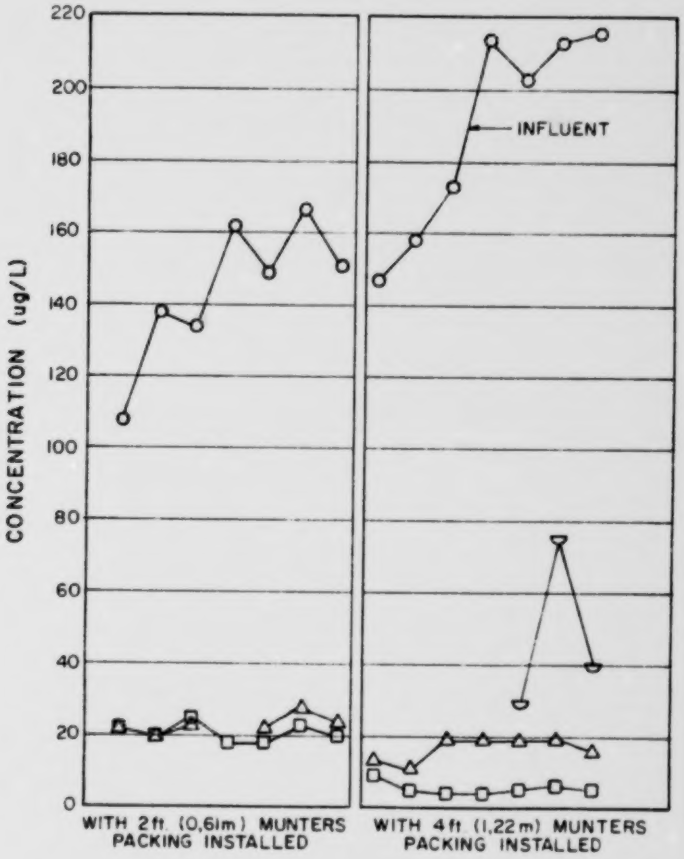
FIGURE 15

The use of a single nozzle (Spraying Systems Co., No. 2HH-30500), positioned near the top center of the column to achieve minimum water contact with the side wall, was next evaluated. The results, as they appear in Table 2C and graphically in Figures 12-15, were not any more promising than those observed with the previous approaches.

Based on the results of all the spray systems tested and visual observations, it was concluded that the contact time between the water and air was insufficient to achieve the removal efficiencies desired. Two methods were considered to increase the contact time: increasing the height of the column or placing packing inside the column. Since the equipment on hand did not allow for increasing the height of the column, but did allow for the installation of packing it was decided to install the packing. The initial testing utilized two feet of the Munters Co. packing purchased for Phase II and the distribution header containing the 5 nozzles. This approach greatly increased the removal efficiencies, achieving better than 80 percent overall removal and achieving a desirable level of contaminant removal. Again the data which are summarized on Table 2D indicated little effect of the air to water ratio on the removal efficiency. Based on these results it was decided to increase the depth of packing in the column to four feet. As shown in Table 2E, this additional packing increased the removal efficiency to greater than 90 percent and achieved a level of remaining organics which should be acceptable in most areas. Due to lack of time in this phase the depth of packing was not increased further. Again, the data presented on Table 2E indicate little effect of air to water ratio on the overall average removal efficiencies. The data for the packing testing is presented schematically on Figures 16 through 19.

In addition to the testing of the spray aeration column using the fan to induce the air flow, several tests were run with the fan off and allowing the water flow to produce a natural draft. Table 2 shows that the natural draft evaluation resulted in contaminant removals greater than 40 percent, and where packing was used, greater than 80 percent. In each case, however, the corresponding removals were greatest when air was induced by the fan. The graphical presentation of the data appears on the figures for the appropriate distribution approach.

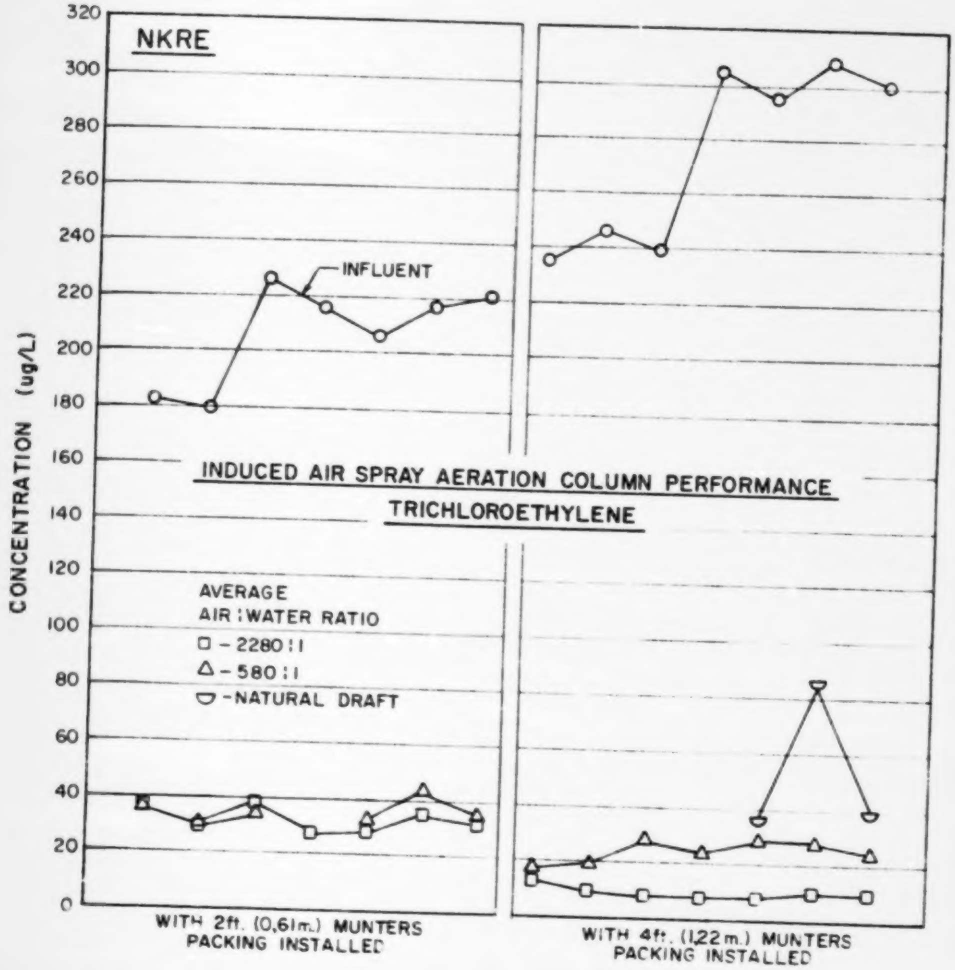
NKRE



INDUCED AIR SPRAY AERATION
COLUMN PERFORMANCE
CIS -1,2 - DICHLOROETHYLENE

AVERAGE
AIR:WATER RATIO
□ - 2280:1
△ - 580:1
▽ - NATURAL DRAFT

FIGURE 16



NKRE
INFLUENT
INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE
TRICHLOROETHYLENE
AVERAGE
AIR : WATER RATIO
□ - 2280 : 1
△ - 580 : 1
▽ - NATURAL DRAFT
CONCENTRATION (ug/L)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
WITH 2ft. (0.61m.) MUNTERS PACKING INSTALLED
WITH 4ft. (1.22m.) MUNTERS PACKING INSTALLED

FIGURE 17

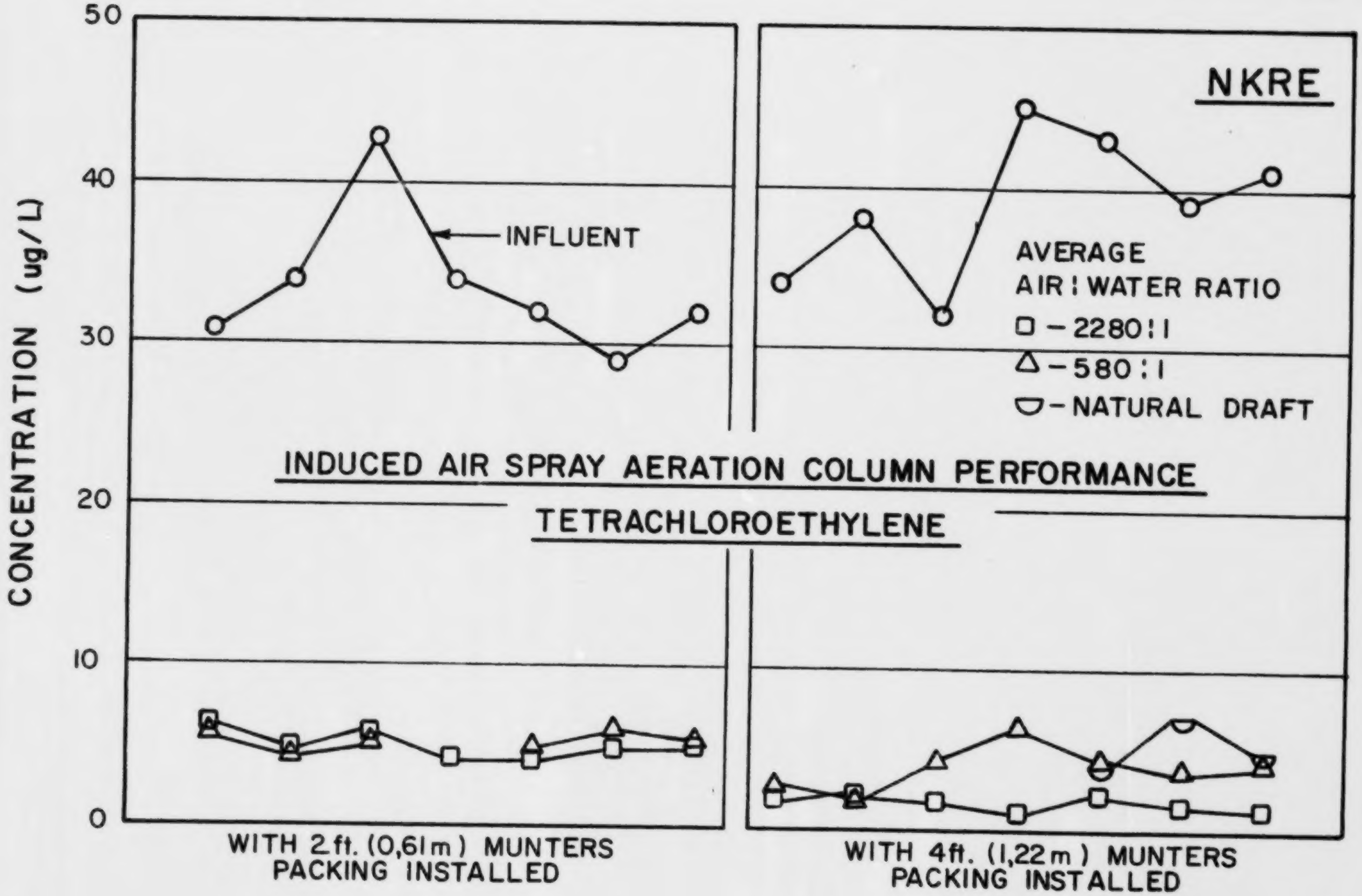
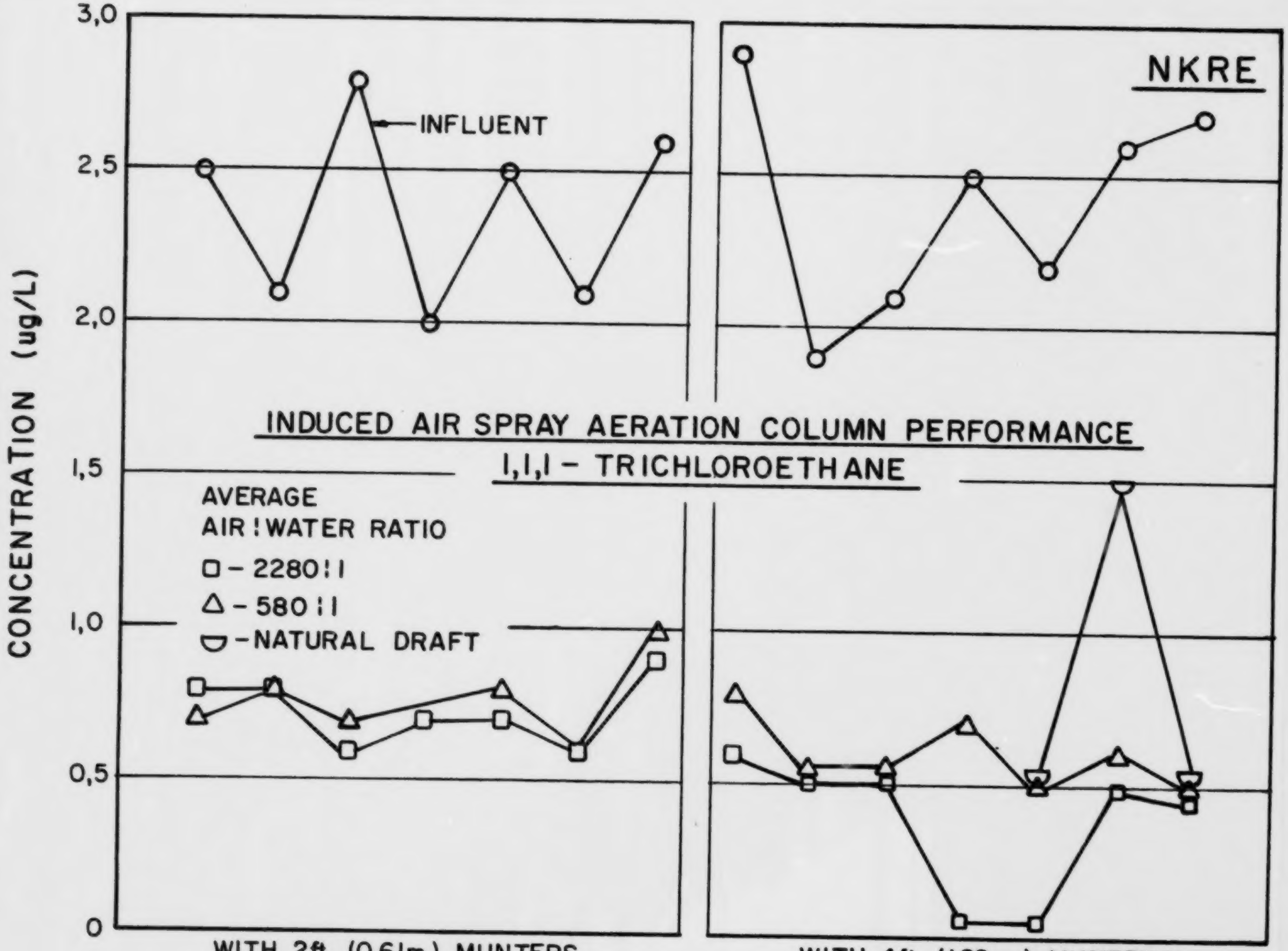

NKRE
INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE
TETRACHLOROETHYLENE
CONCENTRATION (ug/L)
50
40
30
20
10
0
INFLUENT
AVERAGE
AIR : WATER RATIO
□ - 2280 : 1
△ - 580 : 1
◡ - NATURAL DRAFT
WITH 2 ft. (0,61 m) MUNTERS PACKING INSTALLED
WITH 4 ft. (1,22 m) MUNTERS PACKING INSTALLED

FIGURE 18



INDUCED AIR SPRAY AERATION COLUMN PERFORMANCE

1,1,1 - TRICHLOROETHANE

WITH 2ft. (0,61m) MUNTERS PACKING INSTALLED

WITH 4ft. (1,22 m) MUNTERS PACKING INSTALLED

FIG. 19

4. Air-Lift Pumping

The air-lift pump utilized to evaluate air-lifting as an air stripping method was installed in Well No. 20 by the Layne New York Co., Inc. Since there was no commercially available air-lift pump to suit the desired operating conditions, the pump utilized for this testing was fabricated by Layne. The air to water ratio was varied by increasing or reducing both the length of air pipe in the well or air supplied to the well. Since the only data available on air-lift pumping as an air-stripper indicated that a minimum of 10:1 air to water ratio was required, all testing was performed at ratios higher than the minimum. These air to water ratios were much higher than the theoretical computed for air-lift pumping. The results which are presented in Appendix C and summarized on Table 3 indicate that the removal efficiency of this approach to air stripping was low, with only about a 50% reduction in the overall average organic removal. The data also indicate that the air to water ratio had little effect on the removal efficiencies. It should be noted that when this phase started there was very little data on the proper operation of an air-lift pump as an air stripper. Therefore, the relatively poor results obtained were probably attributed to a less-than-optimum pump operation.

The air-lift pump design for installation at Glen Cove was to deliver 50 gpm (190 (Lpm) based on well conditions supplied by Glen Cove personnel. The design conditions (6)(7)(8) were based on a 70 percent submergence (the distance from the pumping water level in the well to the point of air discharge in the well) and a total lift (the distance from the pumping water level in the well to the pump discharge) of approximately 13 feet (0.90 m). A schematic of the air-lift pump showing the design conditions and anticipated well conditions is presented in Appendix A -- the Phase III Work Plan.

During the operation of the air-lift pump the air pipe was altered in an attempt to vary the air to water ratio. At the conclusion of the operation, actual conditions in the well as to pipe lengths and water surfaces were measured. The results of these measurements are shown on the revised air pump schematic presented on Figure 20. The measurements were made mainly to determine the actual static water conditions when Well No. 22 was operating. The following is a tabulation of the submergence and pump efficiency.

Air Pipe Above Pump Head Watertight Seal In ft	Submergence Below Pumping Water Level in ft (D)	Percent Submergence $(\frac{D}{D+h} \times 100)$	Pump Percent Efficiency*	Total Lift in ft (h)
0	17.75	58.3	33.8	12.7
5	12.75	50.1	27.4	12.7
10	7.75	37.9	17.3	12.7

* From Table in Water Supply Engineering - Third Edition(8)

TABLE 3

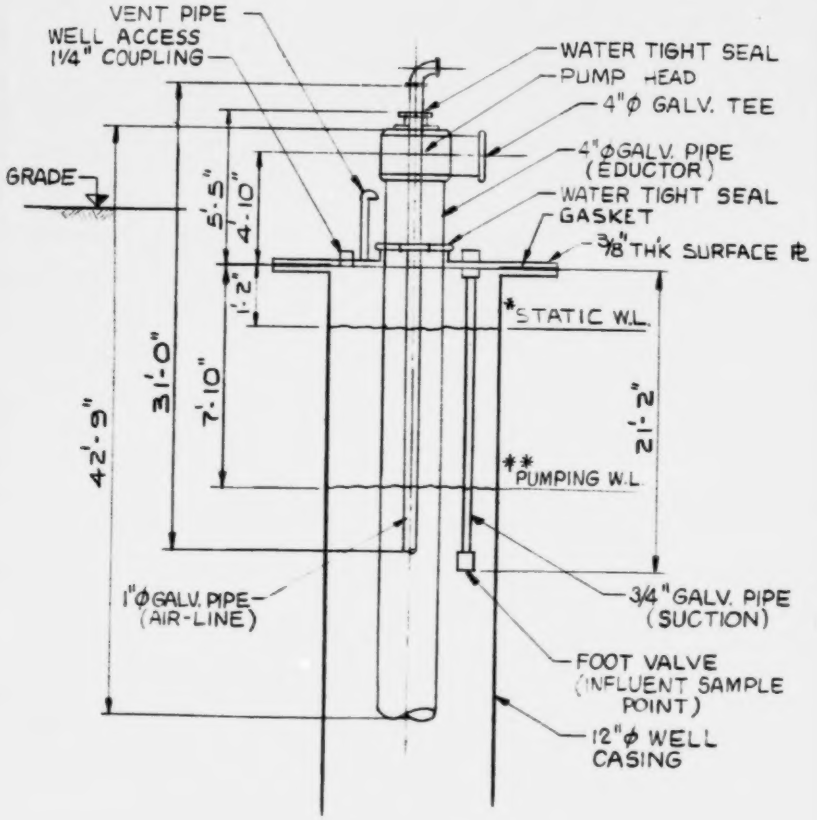
GLEN COVE, N.Y. - PILOT PLANT - PHASE III

AIR-LIFT PUMP SYSTEM

SUMMARY OF RESULTS

(All Values in ug/L)

Air to Water Ratio	Contaminant	Average Inf. (Influent Range)	Average Eff. (Effluent Range)	Average % Removal
15:1 to 27:1	cis-1,2-dichloroethylene	67.1 (28 - 129)	41.7 (18 - 79)	37.8
	trichloroethylene	132.2 (80 - 163)	52.8 (31 - 74)	60.1
	tetrachloroethylene	8.9 (5.8 - 18)	2.9 (1.1 - 6.3)	67.4
	1,1,1-trichloroethane	1.9 (0.9 - 2.9)	0.8 (N.M.- 1.6)	57.9
30:1 to 83:1	cis-1,2-dichloroethylene	70.9 (57 - 137)	52.1 (37 - 76)	26.5
	trichloroethylene	133.5 (99 - 148)	62.6 (45 - 73)	53.1
	tetrachloroethylene	7.6 (6.7 - 9.9)	3.3 (2.5 - 6.2)	56.6
	1,1,1-trichloroethane	1.6 (1.2 - 1.9)	0.8 (0.5 - 1.7)	50.0


VENT PIPE
WELL ACCESS
1¼" COUPLING
WATER TIGHT SEAL
PUMP HEAD
4"ϕ GALV. TEE
GRADE
4"ϕ GALV. PIPE (EDUCTOR)
WATER TIGHT SEAL
GASKET
⅜" THK SURFACE ℞
5'-5"
4'-10"
1'-2"
*STATIC W.L.
42'-9"
31'-0"
7'-10"
21'-2"
**PUMPING W.L.
1"ϕ GALV. PIPE (AIR-LINE)
3/4" GALV. PIPE (SUCTION)
FOOT VALVE (INFLUENT SAMPLE POINT)
12"ϕ WELL CASING

AIR LIFT PUMP

NOTES:

* STATIC WATER LEVEL
** PUMPING WATER LEVEL (WITH WELL 22 RUNNING APPROX 6'-8" INFLUENCE)
AIR & EDUCTOR PIPE SETTINGS ADJUSTABLE

FIGURE 20

These data indicate the poor efficiency of the air-lift pumping installation installed at Glen Cove, N.Y.

5. Packed Column Air Stripper at Glen Cove

Twice during the Phase III field testing period U.S. EPA personnel installed and operated their Packed Column Air Stripper(9) at the Glen Cove, N.Y. site. During these test periods, which occurred in August and December of 1982, NKRE personnel assisted in the assembly and operation of this test column and performed a limited amount of analyses. The Packed Column Air Stripper, shown in Figure 2, has 18 sampling ports within the 18 ft (5.5 m) of packing material. The first sample port is 0.5 ft (0.15 m) into the top of the packing material and from that point the sample ports are spread 1 ft (0.3 m) apart terminating at 17.5 ft (5.3 m) from the top of the packing. In addition, a final sampling port was located at the final effluent point of the column and samples were taken at the source of water supply to the column. During the testing period at Glen Cove, N.Y., the U.S. EPA personnel sampled each port for each air to water ratio evaluated, while NKRE personnel sampled only those ports believed relevant to the Glen Cove project. These included the source or influent supply, the first port at 0.5 ft (0.15 m) from the top of packing and teh effluent for all tested air to water ratios. During the first sample period, in August 1982, 1-inch (2.5 cm) plastic saddles were used, and samples were also taken at the mid-point sample port or 9.5 ft (2.9 m) from the packing surface and the final sample port of the packing, 17.5 ft (5.3 m) from the surface. During the second testing period, in December 1982, both 1-inch (2.5 cm) and 2-inch (5.0 cm) plastic saddles were utilized. During the testing of the 1-inch (2.5 cm) saddles, samples were taken by NKRE personnel at the 13.5 ft (4.1 m) sample port since the U.S. EPA had computed this depth of packing as that required for 95% removal of trichloroethylene under the Glen Cove conditions utilizing an approximate 20 to 1 air to water ratio. The analyses performed on site by NKRE personnel along with the percentage of contaminant removal are presented in Appendix C and summarized on Table 4.

The results show that this approach to aeration as a method of removing volatile organic contaminants can achieve a desirable removal level. Utilizing a system similar to the design of the test column and using 1-inch (2.5 cm) saddles as packing it is possible to achieve effluent levels meeting present New York State Guidelines and levels which should be acceptable in most areas at air to water ratios of 15 to 1 or greater. These ratios should achieve greater than 90 percent removal of all contaminants and produce effluents with total concentrations of the four contaminants less than 40 ug/L.

TABLE 4

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

U.S. EPA PACKED COLUMN AIR STRIPPER

SUMMARY OF RESULTS

(All Values in ug/L)

Air to Water Ratio	Contaminant	Average* Influent (Influent Range)	Average Effluent (Effluent Range)	Average % Removal for Contamin.	Average % Removal for all Contamin.
A.	Using 1" (2.5 cm) plastic saddles as packing				
85:1**	cis-1,2-dichloroethylene	191.8	< 0.5	> 99.7	
	trichloroethylene	292.8 (223-344)	< 0.5	> 99.8	
	tetrachloroethylene	48.8 (38-72)	< 0.5	> 99.1	
	1,1,1-trichloroethane	3.4 (2.7-4.8)	< 0.5	> 86.7	> 96.3
45:1	cis-1,2-dichloroethylene		0.65 (0.5-0.8)	99.7	
	trichloroethylene		< 0.6 (0.5-0.7)	> 99.8	
	tetrachloroethylene		< 0.5	> 99.0	
	1,1,1-trichloroethane		< 0.5	> 85.2	> 95.9

(Cont'd)

---

* Average influent and influent range is the same for all air:water ratios.
**Based on one day of testing.

TABLE 4

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

U.S. EPA PACKED COLUMN AIR STRIPPER

SUMMARY OF RESULTS

(All Values in ug/L)
(Continued)

Air to Water Ratio	Contaminant	Average* Influent (Influent Range)	Average Effluent (Effluent Range)	Average % Removal for Contamin.	Average % Removal for all Contamin.
25:1	cis-1,2-dichloroethylene		9.1 (8.4-9.8)	95.3	
	trichloroethylene		3.95 (3.8-4.1)	98.6	
	tetrachloroethylene		<0.6 (0.5-0.7)	>98.8	
	1,1,1-trichloroethane		<0.95 (0.5-1.4)	>71.9	>91.2
15:1	cis-1,2-dichloroethylene		24.5 (19-30)	87.2	
	trichloroethylene		10.4 (7.7-13.0)	96.2	
	tetrachloroethylene		0.8 (0.6-1.0)	98.3	
	1,1,1-trichloroethane		<0.6 (<0.5-0.7)	>82.2	>91.1
10:1**	cis-1,2-dichloroethylene		49	71.1	
	trichloroethylene		31	87.1	
	tetrachloroethylene		2.7	95.3	
	1,1,1-trichloroethane		0.5	86.7	85.1

(Cont'd)

---

* Average influent and influent range is the same for all air:water ratios.

** Based on one day of testing

TABLE 4

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

U.S. EPA PACKED COLUMN AIR STRIPPER

SUMMARY OF RESULTS

(All Values in ug/L)
(Continued)

Air to Water Ratio	Contaminant	Average* Influent (Influent Range)	Average Effluent (Effluent Range)	Average % Removal for Contamin.	Average % Removal for all Contamin.
8:1**	cis-1,2-dichloroethylene		80	62.6	
	trichloroethylene		53	84.6	
	tetrachloroethylene		3.5	91.3	
	1,1,1-trichloroethane		1.2	60.0	74.6
5:1**	cis-1,2-dichloroethylene		79	53.4	
	trichloroethylene		77	67.9	
	tetrachloroethylene		8.6	84.9	
	1,1,1-trichloroethane		1.0	73.3	69.9
Natural Draft	cis-1,2-dichloroethylene		144	32.7	
at 84.8	trichloroethylene		195	43.6	
gpm flow	tetrachloroethylene		16	60.5	
rate**	1,1,1-trichloroethane		2.0	33.3	38.2

(Cont'd)

---

* Average influent and influent range is the same for all air:water ratios.
** Based on one day of testing.

TABLE 4
GLEN COVE, N.Y. - PILOT PLANT - PHASE III
U.S. EPA PACKED COLUMN AIR STRIPPER
SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

Air to Water Ratio	Contaminant	Average* Influent (Influent Range)	Average Effluent (Effluent Range)	Average % Removal for Contamin.	Average % Removal for all Contamin.
B.	Results at theoretical depth (13.5 ft/4.1 m) of packing of the column for Glen Cove conditions (using 1" (2.5 cm) plastic saddles as packing) (All results based on one day of testing)				
45:1**	cis-1,2-dichloroethylene	214	6.8	96.8	
	trichloroethylene	345.5 (314-347)	5.4	98.4	
	tetrachloroethylene	40.5 (39-42)	<0.5	>98.8	
	1,1,1-trichloroethane	3.0 (2.9-3.1)	<0.5	>83.3	>94.3
25:1**	cis-1,2-dichloroethylene		35	83.6	
	trichloroethylene		24	93.1	
	tetrachloroethylene		1.1	97.3	
	1,1,1-trichloroethane		<0.5	>83.3	>89.3
15:1**	cis-1,2-dichloroethylene		88	58.9	
	trichloroethylene		57	83.5	
	tetrachloroethylene		3.1	92.3	
	1,1,1-trichloroethane		1.2	60.0	73.7

(Cont'd)

---

* Average influent and influent range is the same for all air:water ratios.

** Based on one day of testing.

TABLE 4

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

U.S. EPA PACKED COLUMN AIR STRIPPER

SUMMARY OF RESULTS

(All Values in ug/L)
(Continued)

Air to Water Ratio	Contaminant	Average* Influent (Influent Range)	Average Effluent (Effluent Range)	Average % Removal for Contamin.	Average % Removal for all Contamin.
8:1**	cis-1,2-dichloroethylene		166	22.4	
	trichloroethylene		155	55.1	
	tetrachloroethylene		8.6	78.8	
	1,1,1-trichloroethane		2.0	33.3	47.4
Natural draft at 84.8 gpm flow rate **	cis-1,2-dichloroethylene		172	19.3	
	trichloroethylene		244	29.4	
	tetrachloroethylene		29	28.4	
	1,1,1-trichloroethane		2.5	16.7	27.6
C.	Using 2" (5.0 cm) plastic saddles as packing (Based on one day of testing)				
45:1**	cis-1,2-dichloroethylene	204 (193-218)	3.1	98.5	
	trichloroethylene	340 (330-345)	3.7	98.9	
	tetrachloroethylene	42.3 (39-46)	0.6	98.6	
	1,1,1-trichloroethane	3.0 (2.7-3.2)	<0.5	>83.3	>94.8

(Cont'd)

---

* Average influent and influent range is the same for all air:water ratios.
**Based on one day of testing.

TABLE 4

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

U.S. EPA PACKED COLUMN AIR STRIPPER

SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

Air to Water Ratio	Contaminant	Average* Influent (Influent Range)	Average Effluent (Effluent Range)	Average % Removal for Contamin.	Average % Removal for all Contamin.
25:1**	cis-1,2-dichloroethylene		11	94.6	
	trichloroethylene		10	97.1	
	tetrachloroethylene		1.2	97.2	
	1,1,1-trichloroethane		0.5	83.3	93.1
15:1**	cis-1,2-dichloroethylene		39	80.9	
	trichloroethylene		22	93.5	
	tetrachloroethylene		2.6	93.9	
	1,1,1-trichloroethane		0.5	83.3	87.9
8:1**	cis-1,2-dichloroethylene		75	63.2	
	trichloroethylene		55	83.8	
	tetrachloroethylene		5.0	88.2	
	1,1,1-trichloroethane		0.9	70.0	76.3
5:1**	cis-1,2-dichloroethylene		116	43.1	
	trichloroethylene		100	70.6	
	tetrachloroethylene		7.7	81.8	
	1,1,1-trichloroethane		1.3	56.7	63.1

(Cont'd)

---

* Average influent and influent range is the same for all air:water ratios.

** Based on one day of testing.

TABLE 4

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

U.S. EPA PACKED COLUMN AIR STRIPPER

SUMMARY OF RESULTS

(All Values in ug/L)

(Continued)

Air to Water Ratio	Contaminant	Average* Influent (Influent Range)	Average Effluent (Effluent Range)	Average % Removal for Contamin.	Average % Removal for all Contamin.
Natural Draft at 38.5 gpm flow rate**	cis-1,2-dichloroethylene		82	59.8	
	trichloroethylene		69	79.7	
	tetrachloroethylene		4.2	90.1	
	1,1,1-trichloroethane		1.3	56.7	71.6

---

* Average influent and influent range is the same for all air:water ratios.

** Based on one day of testing.

For the theoretical column height (13.5 feet of packing) for Glen Cove, air to water ratios greater than 25 to 1 or a higher column would be required to achieve an overall removal of greater than 90 percent for all contaminants or 95 percent for trichloroethylene.

The results from the single day testing utilizing the 2-inch (5.0 cm) plastic saddles were similar to those obtained utilizing the 1-inch (2.5 cm) plastic saddles for almost all air to water ratios examined. The major evaluation as to the advantage of one size over the other must be based on cost.

The use of natural draft was accomplished by disconnecting the blower from the column and allowing the water flow to cause the induction of air. The results of this approach utilizing the U.S. EPA column did not indicate a removal acceptable under any conditions. It must be noted that the testing was only attempted at two air flows, one for each size saddle, and removals might be improved at greater flow application rates. The major consideration for using this approach must be the cost savings achieved by not utilizing the mechanical air inducing device.

6. Particulate/Suspended Solids Measurements

When aeration methods are used to treat a drinking water supply, the concern exists that contaminants present in the ambient air might be transferred to the water, requiring additional treatment prior to use. In an attempt to evaluate the transfer of particulate matter from the air into the water, suspended solids and particulate analyses were performed at various times during Phase III. The suspended solids analyses were run on site by NKRE personnel while the particulate analyses were performed by U.S. EPA personnel in Cincinnati. The results of these samplings, which are presented in Appendix C, show little effect on the water supply. In general, suspended solids analyses on both influent and effluent waters of all test units were less than 0.1 mg/l which is the accuracy of the analytical equipment (balance) utilized in the analysis.

It should be noted that the ambient air is relatively clean in the Glen Cove, N.Y. area and that different results may be found in areas where ambient would contain high quantities of particulate matter. No attempt was made to determine the adsorbancy of other potential pollutants from the ambient air by the water.

7. Air Sampling

The use of aeration as a treatment technology for volatile organics has raised a concern about the transfer of contaminants from the water to the ambient air, thereby causing an air pollution problem. To study this problem, air sampling and analysis of ambient air, the air discharging the diffused aeration column, the spray aeration column, the air-lift pump and the U.S. EPA Packed Column Air Stripper were performed by New York Testing Laboratories, Inc. A report prepared by New York Testing on the entire sampling program is presented in Appendix C. Also included in Appendix C is a table comparing the actual air analysis performed by New York Testing and the computed theoretical value, along with the basic data used to compute the theoretical value.(10)(11) These data are summarized on Table 5 along with the OSHA 8-hr work room Standards for the contaminants.(12) In many instances the levels found were higher than the computed theoretical value. This discrepancy was reviewed with New York Testing and they believe it was due to the pickup of moisture in the actual air sampling. Their suggested solution was that if a mist eliminator had been placed at the discharge of each aeration or air stripping device the actual value would have been much closer to the computed value. It was not possible to compute a theoretical value for the air-lift pump system since it was impossible to measure the air discharging the system's stilling basin. When comparing the actual analytical results or the computed theoretical values for the discharged air with the OSHA Standards it is apparent that none of the aeration systems had any appreciable impact on contamination of the air in the vicinity of the units and, after dilution with the contaminant-free ambient air, contaminant levels would probably not be measurable.

8. Summary

The data presented below can be used as a comparison of removal efficiencies obtained from four possible aeration methods evaluated during this study for the four volatile organics present in Glen Cove's ground water. The following is an indication of the range of overall removals for each system depending on the air to water ratio used.

System	Range of Overall Percent Removal**
Diffused Aeration	59-78
Spray Aeration	
1) Without packing	
- Induced air	52-77
- Natural draft	43-63
2) With 2 ft (0.61 m) packing	
- Induced air	80-82
3) With 4 ft (1.22 m) packing	
- Induced air	91-93
- Natural draft	81*

System	Range of Overall Percent Removal**
U.S. EPA-Packed Column Air Stripper	
1) With 1-inch (2.5 cm) saddles	
- Induced air	69-97
- Natural draft	38*
2) With 2-inch (5.0 cm) saddles	
- Induced air	63-95
- Natural draft	72*
Air-lift Pumping	46-56

* Results based on one day of testing
** Function of air to water ratio

This summary indicates that the best removal was achieved by the U.S. EPA-Packed Column Air Stripper closely followed by the Spray Aeration with packing system. In essence, these systems used basically the same approaches but with different packing materials. The diffused aeration system did not operate as well as in the other phases and its results were closely followed by the spray aeration system without packing. The air-lift pumping approach achieved the lowest overall removal. However, the operation of this system was not at optimum conditions. The natural draft approach tested on systems where induced ambient air is utilized indicated fair removals especially when considering the results of induced air spray aeration testing. By reviewing the data presented on the previous table, it is apparent that the natural draft approach operates best when large openings in the media are present, since the best results for the packed column air stripper occurred when the large saddles were installed and the packing used in the induced air spray aeration approach contained large openings. This is based on the test conditions at the Glen Cove pilot plant and might be different under other test conditions. In general, aeration can be used to meet drinking water quality in most areas.

B. ADSORPTION STUDIES - RESIN COLUMNS

1. General

The Phase III pilot plant program continued evaluation of resin adsorption as a treatment method for removing trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene, and 1,1,1-trichloroethane from groundwater used as a source of drinking water.

TABLE 5

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

AIR SAMPLING AND ANALYSIS

SUMMARY OF RESULTS

(All values in ppm - volume to volume)

A. Analyses at Glen Cove Site

	Testing	Contaminant	Average Values Found	Average Computed Theoretical Values
1.	U.S. EPA Packed Column Air Stripper*	cis-1,2-dichloroethylene	11.608	1.99
		trichloroethylene	7.354	2.53
		tetrachloroethylene	0.700	0.29
		1,1,1-trichloroethane	N.D.	0.02
2.	Diffused Aeration Column	cis-1,2-dichloroethylene	3.868	1.84
		trichloroethylene	6.163	2.74
		tetrachloroethylene	0.250	0.39
		1,1,1-trichloroethane	1.225	0.04
3.	Spray Aeration Column	cis-1,2-dichloroethylene	N.D.	0.02
		trichloroethylene	N.D.	0.02
		tetrachloroethylene	N.D.	0.01
		1,1,1-trichloroethane	N.D.	0.01
4.	Air-lift Pump*	cis-1,2-dichloroethylene	N.D.	Not possible to calculate
		trichloroethylene	N.D.	
		tetrachloroethylene	N.D.	
		1,1,1-trichloroethane	N.D.	
5.	Ambient Air	cis-1,2-dichloroethylene	N.D.	Not Applicable
		trichloroethylene	N.D.	
		tetrachloroethylene	N.D.	
		1,1,1-trichloroethane	N.D.	

B. OSHA Standards

(Time weighted average - 8 hr period)$^{(12)}$

Contaminant	Standard
cis-1,2-dichloroethylene	200
trichloroethylene	100
tetrachloroethylene	100
1,1,1-trichloroethane	350

NOTE: Analytical detectable limits: 0.5 ppm
N.D. - Not detectable (<0.5 ppm)

* Based on two sampling occurrences. All others based on four occurrences.

Resin testing conducted during Phase II demonstrated that countercurrent operation of the resin columns (downward flow application and upward steam regeneration) was the best mode of operation. All of the resin columns utilized in Phase III were installed to operate in this mode. The results of the data from Phases I and II indicated that the use of a combined aeration-adsorption treatment system approach to maximize the efficiency of organic contaminant removal should be evaluated. A combined system utilizing aeration for primary contaminant reduction followed by resin adsorption to produce a polished effluent was designed and installed in Phase III. Of the seven columns operating during Phase III, Columns I through IV received water directly from Well #22, and Columns V through VII were supplied with water from the diffused aeration column (Figure 1). (The diffused aeration column's source of water was the same as that for Columns I-IV, Well #22).

Based on a recommendation resulting from Phase II resin testing, determination of the optimum hydraulic loading of the resin became an objective for Phase III adsorption studies. The 4 gpm/ft3 (0.42 Lpm/m3) application rate used in Phases I and II reduced contaminant levels to less than 1 ug/L with virgin and freshly regenerated resin for the influent concentrations present. (These findings are presented in reports EPA-600/2-80-198 and EPA-600/2-82-027). The use of 4 gpm/ft3 (0.42 Lpm/m3) was recommended by the resin manufacturer, Rohm and Haas, based on laboratory studies in which the resin effectively demonstrated chloroform removal from surface water at this application rate.

The results of the previous phases using an application rate of 4 gpm/ft3 (0.42 Lpm/m3) appeared to indicate that the resin could withstand higher hydraulic loadings. The proper hydraulic loading and contact times were uncertain and, therefore, various application rates were examined during Phase III. For the direct treatment system, the application rates were as follows: Column I: 4 gpm/ft3 (0.42 Lpm/m3), Column II: 4 gpm/ft3 (0.42 Lpm/m3), Column III: 8 gpm/ft3 (0.83 Lpm/m3), and Column IV: 12 gpm/ft3 (1.26 Lpm/m3). For the resin system receiving water after aeration, the application rates were 8 gpm/ft3 (0.83 Lpm/m3), 12 gpm/ft3 (1.26 Lpm/m3), and 16 gpm/ft3 (1.66 Lpm/m3) for Columns V, VI, and VII, respectively. The operation of the resin testing systems is further described in the Testing Program and Operation section of this report and in the Work Plan presented in Appendix A.

The resin utilized in Phase III was Ambersorb XE-340 ^{R}, the same as that used in Phases I and II. Ambersorb XE-340 ^{R} was developed by Rohm and Haas to effect the removal of relatively non-polar organic molecules and halogenated aliphatics from water.

2. Determination of Unacceptable Resin

Columns I-IV were put on line on October 14, 1981, and Columns V-VII the following day. After 6 days in operation, breakthrough of the three major contaminants was evident in all of the columns. The resin in Columns II-VII was removing cis-1,2-dichloroethylene more effectively than trichloroethylene, the opposite of what had been observed during previous resin testing. This reverse pattern of contaminant removal effectiveness was not seen in Column I, which contained the regenerated resin previously used in Phases I and II. The explanation for the premature breakthrough and abnormal removal effectiveness of the resin was not immediately known. Investigations to determine the reason(s) for the unsatisfactory performance of the resin were begun while the columns continued operating at the water flow rates needed to maintain the prescribed application rates.

The Ambersorb® XE-340 supplied by Rohm and Haas for Phase III was hydrated with methanol at the production plant prior to shipment to the water plant site and was placed in Columns II-VII after arrival at Glen Cove. During Phases I and II, however, the hydration step was performed at the project site. Therefore, the cause of the premature breakthrough was initially attributed to this difference. Total or partial dehydration of the resin drying shipment was conjectured to have occurred. This explanation was not considered further when no evidence of floating resin was observed.

Next, regenerations of Columns II (from 1/27/82 to 1/28/82) and V (from 1/29/82 to 2/3/82) were carried out to determine whether that step might restore the resin to virgin conditions, but no improvement in performance was observed when the columns were placed in operation.

A complete inorganic and organic characterization of the well water was made by the DWRD, EPA-Cincinnati, to assess whether the water quality had substantially changed, thereby affecting the resin performance. But no appreciable changes were noted.

On February 25, 1982, the resin in Column III was replaced with freshly hydrated virgin resin from the same batch originally supplied for Phases I and II. At the same time, the resin in Column IV was replaced with the original resin supplied for Phase III, so that a parallel evaluation of performance could be made. Both columns were operated at a water flow rate of 42 gallons per hour (application rate = 4 gpm/ft3 (0.42 Lpm/m3)) After a few days, it was obvious that the contaminant removal efficiency of the resin provided for Phase III use was significantly less than that of the resin used during Phases I and II. This finding was further supported when the resin in Column VII was emptied, refilled with Phases I and II resin and operated at a water flow rate of 42 gallons per hour (application rate: 4 gpm/ft3 (0.42 Lpm/m3)).

The conclusion was reached that the resin supplied for Phase III was defective. Rohm and Haas, the resin manufacturer, conducted adsorption isotherm testing on the virgin resins supplied for Phases I, II, and III and found nearly identical adsorption capacities. A comparative screen analysis was done by Rohm and Haas to determine the particle size distribution of the resin supplied for Phases I and II and that supplied for Phase III, the results of which are presented in Appendix D and revealed the following: the material used in Phase III (Lot #2-9387) contained many more large beads in the (-16+30) mesh range than the resin used in Phases I and II (72 percent vs. 45 percent). Although the capacities were similar, the larger particle-sized resin did not perform kinetically as well, according to Rohm and Haas.

The manufacturer provided one cubic foot of Ambersorb ® XE-340 (Lot # JJM2998A) for continuation of the test period. The resin was hydrated at the project site and columns II, IV, V, and VI were filled with the new resin before being put back on line on March 31, 1982. Since the high application rates were not considered feasible, some changes in flow rates were made. Column II was operated at an application rate of 4 gpm/ft3 (0.42 Lpm/m3), Column IV at 8 gpm/ft3 (0.83 Lpm/m3), Column V at 4 gpm/ft3 (0.42 Lpm/m3), and Column VI at 12 gpm/ft3 (1.26 Lpm/m3). As was the case for the previous testing of resin during Phase III, Columns I-IV received water directly from Well #22, and Columns V-VI received water from the diffused aeration column.

All columns were closely monitored for the next eight weeks. Columns III and VII, containing resin from Phases I and II, continued to exhibit contaminant removal efficiencies which surpassed the original Phase III resin. Columns II, IV, V, and VI performed in a similar fashion, displaying removal patterns more consistent with Phases I and II.

Column IV (application rate = 8 gpm/ft3 (0.83 Lpm/m3)) and Column VI (application rate = 12 gpm/ft3 (1.26 Lpm/m3) were being utilized to determine if the resin could tolerate higher hydraulic loadings than the 4 gpm/ft3 (0.42 Lpm/m3) rate of the other columns. The effluent levels from Columns IV and VI definitely showed that the rate at which the resin was exhausted was a function of the applied hydraulic loading. Saturation of the resin by trichloroethylene and tetrachloroethylene and ensuing breakthrough was much more rapid at the higher application rates for both the unaerated and aerated waters. This was also true for cis-1,2-dichloroethylene, but the difference in the effluent levels at the higher and lower application rates were not as extreme as for trichloroethylene and tetrachloroethylene. Further testing to determine the optimum hydraulic loading rate of the resin using lower hydraulic loadings was indicated.

3. Resin Treatment Without Prior Aeration

On June 2, 1982 Columns III and IV were filled with resin from a second cubic foot of the acceptable resin, Lot #JJM 2998A, shipped to the pilot plant by Rohm and Haas. Column II, filled during the test period with resin from the first cubic foot, was left on line at an application rate of 4 gpm/ft3 (0.42 Lpm/m3).

When reviewing the data (Figures 21-23) developed during the period of confirming the adaptability of the second resin supplied for Phase III (Lot # JJM2998A) the higher hydraulic load used during the period, 8 gpm/ft3 (0.84 Lpm/m3), exhibited breakthrough much earlier than the normally recommended application rate of 4 gpm/ft3 (0.42 Lpm/m3). For example, if a target level of 10 ug/L were chosen, service times for trichloroethylene and tetrachloroethylene would be:

	Days of Operation	
	4 gpm/ft3 (0.42 Lpm/m3)	8 gpm/ft3 (0.84 Lpm/m3)
Trichloroethylene	38	8
Tetrachloroethylene	68	12

Based on this appraisal, hydraulic loading rates of 2 gpm/ft3 (0.21 Lpm/m3) and 6 gpm/ft3 (0.63 Lpm/m3) were used for Columns III and IV, respectively in a further effort to determine the optimum hydraulic loading which could be applied to the resin.

Columns II, III and IV each contained 2 feet (0.61 m) of virgin resin. The application rate for Column II was 4 gpm/ft3 (0.42 Lpm/m3) which resulted in an empty bed contact time (EBCT) of approximately 1.9 minutes or 772.1 bed volumes per day (BV/d). The 2 gpm/ft3 rate (0.21 Lpm/m3) for Column III corresponded to an EBCT of approximately 3.8 minutes or 361.1 BV/d. Column IV's application rate of 6 gpm/ft3 (0.63 Lpm/m3) produced an EBCT of 1.2 minutes or 1,083 BV/d. The countercurrent mode of operation with downward flow application and upward steam regeneration was used in each as a result of Phase II testing which demonstrated superior performance in this mode.

The performance of the resin columns is displayed on Figures 21 through 24. The 8 gpm/ft3 (0.84 Lpm/m3) application rate that was used in Column IV during the test period is also presented in the figures for comparative purposes. To avoid confusion this column will be referred to hereafter as Column IV-8.

Visual examination of Figures 21 through 24 reveals the rapid upward slope observed in the breakthrough curves for cis-1,2-dichloroethylene at all application rates tested. The effluent levels for cis-1,2-dichloroethylene from all columns surpassed the influent level (not shown on the plots) after various lengths of time of column operation. Column effluent levels for the other two major contaminants never exceeded the influent levels for these contaminants at any of the application rates used. These observations support the conclusion reached in Phase II that the resin was least effective in removing the cis compound.

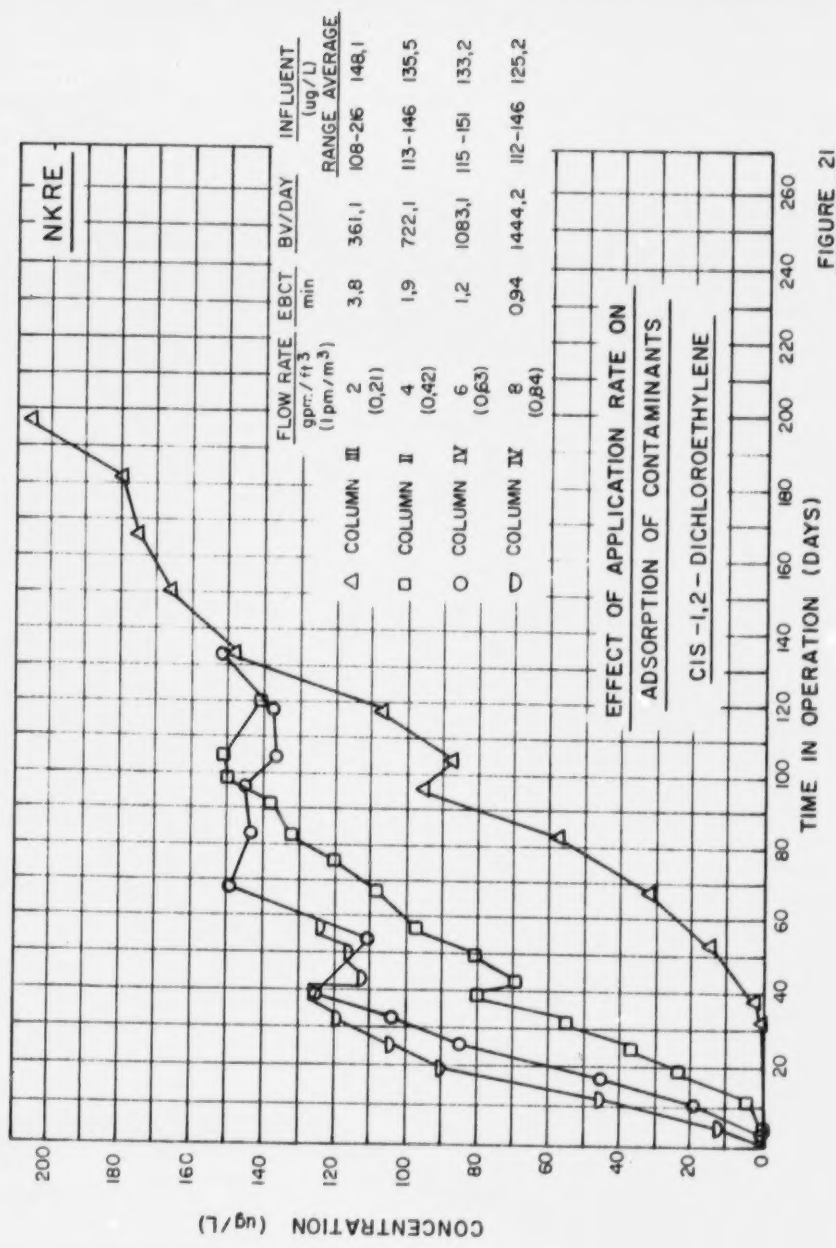
Figures 21-23 show that breakthrough occurred soonest for the 8 gpm/ft3 (0.84 Lpm/m3) application rate and latest at 2 gpm/ft3 (0.21 Lpm/m3) for the major contaminants. This indicated that the rate at which the resin was being saturated had a direct relationship to the applied hydraulic loading.

Significant differences in service time are observed as a function of application rate. For the cis compound and for trichloroethylene, the following service times were achieved to meet the New York State guidelines of 50 ug/L:

Application Rate (gpm/ft3)	Service Time to Reach 50 ug/L in Effluent (days)	
	cis-1,2-dichloroethylene	trichloroethylene
2	78	185
4	30	63
6	18	37
8	12	16

4. Resin Treatment After Aeration

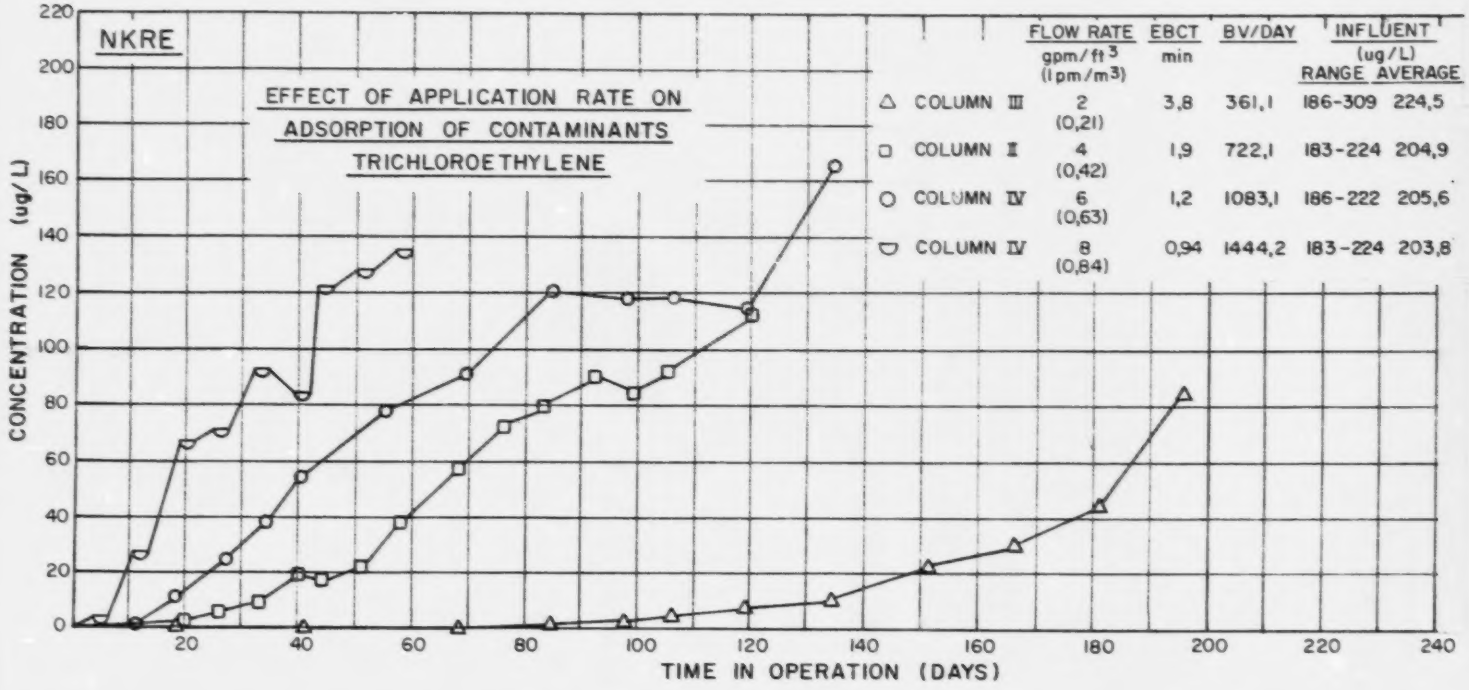
Columns V, VI and VII were filled from the second cubic foot of acceptable resin, Lot #JJM 2998A, and put on line on June 2, 1982. Based on Column VI's unfavorable performance at an application rate of 12 gpm/ft3 (1.26 Lpm/m3) during the initial portion of the Phase III test period, lower hydraulic loadings were applied to these columns when they were put into operation with the acceptable resin. Another change that was



EFFECT OF APPLICATION RATE ON ADSORPTION OF CONTAMINANTS

CIS-1,2-DICHLOROETHYLENE

FIGURE 21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EFFECT OF APPLICATION RATE ON
ADSORPTION OF CONTAMINANTS
TRICHLOROETHYLENE
FLOW RATE gpm/ft^3 (lpm/m^3)
EBCT min
BV/DAY
INFLUENT (ug/L) RANGE AVERAGE
△ COLUMN III 2 (0,21) 3,8 361,1 186-309 224,5
□ COLUMN II 4 (0,42) 1,9 722,1 183-224 204,9
○ COLUMN IV 6 (0,63) 1,2 1083,1 186-222 205,6
◡ COLUMN IV 8 (0,84) 0,94 1444,2 183-224 203,8
CONCENTRATION (ug/L)
0
20
40
60
80
100
120
140
160
180
200
220
TIME IN OPERATION (DAYS)
20
40
60
80
100
120
140
160
180
200
220
240

FIGURE 22

	FLOW RATE gpm/ft 3 (lpm/m 3)	EBCT min	BV/DAY	INFLUENT (ug/L) RANGE	INFLUENT (ug/L) AVERAGE
△ COLUMN III	2 (0,21)	3,8	361,1	31-50	39,8
□ COLUMN II	4 (0,42)	1,9	722,1	34-50	41,2
○ COLUMN IV	6 (0,63)	1,2	1083,1	31 -50	39,5
▽ COLUMN IV	8 (0,84)	0,94	1444,2	34-50	40

EFFECT OF APPLICATION RATE ON ADSORPTION OF CONTAMINANTS

TETRACHLOROETHYLENE

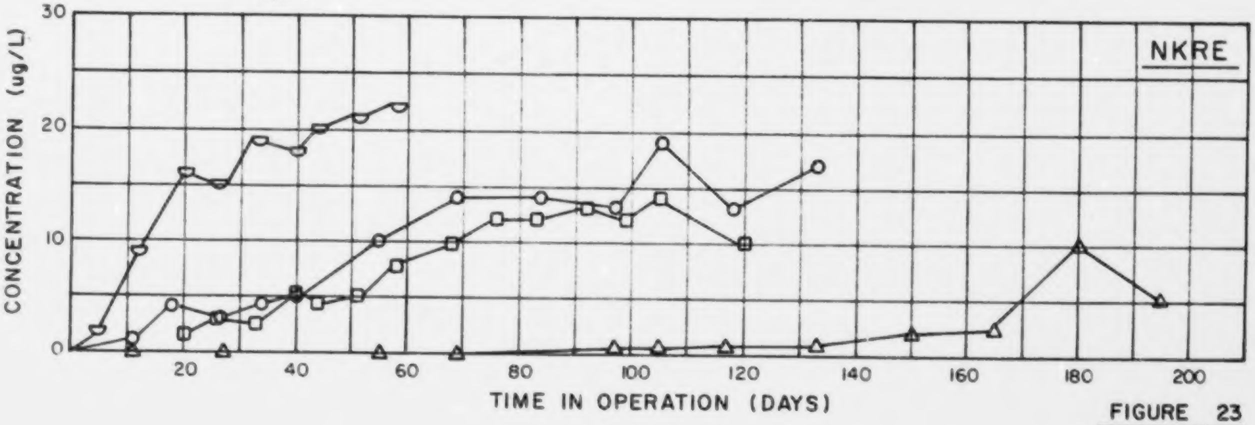
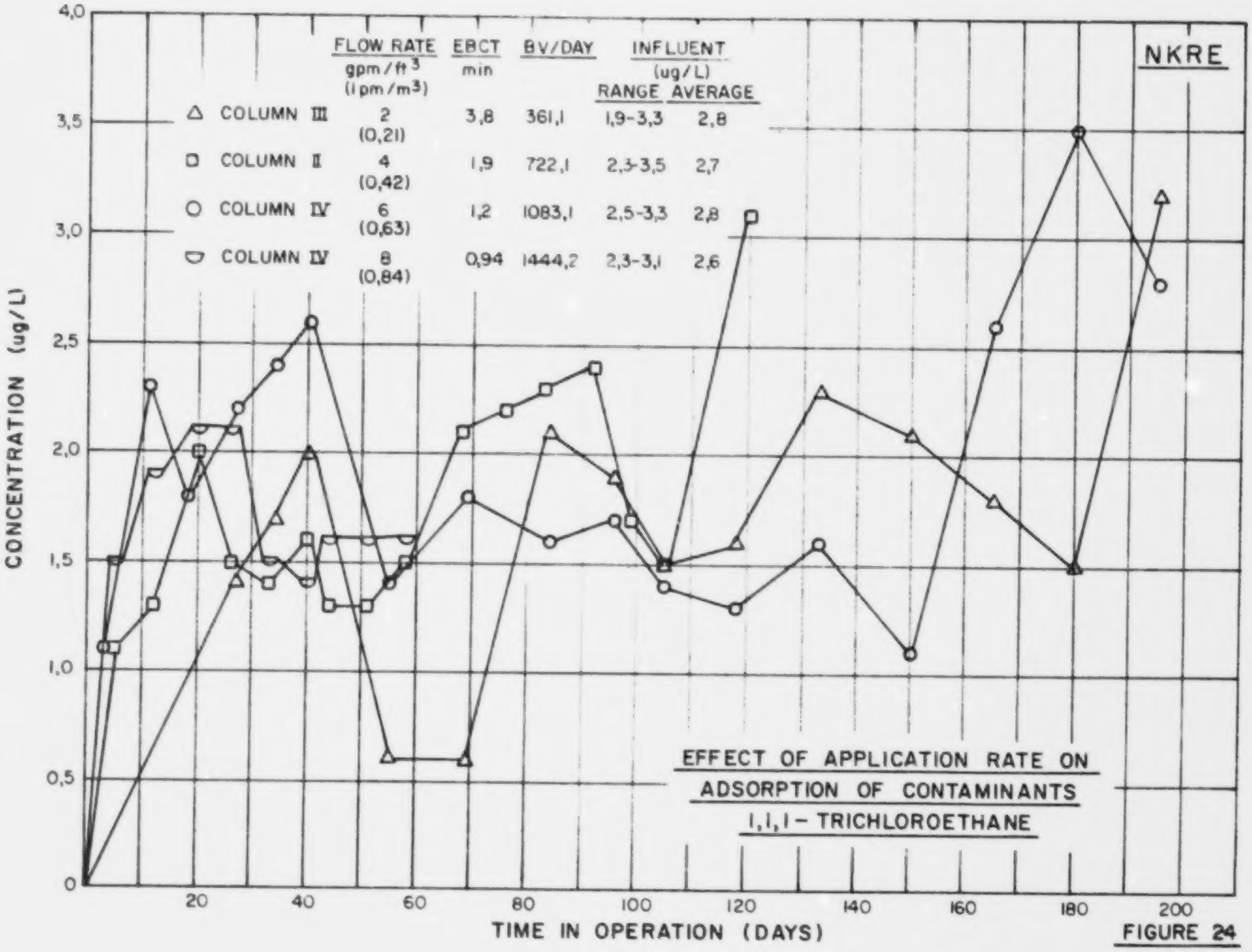


FIGURE 23



EFFECT OF APPLICATION RATE ON ADSORPTION OF CONTAMINANTS

1,1,1- TRICHLOROETHANE

FIGURE 24

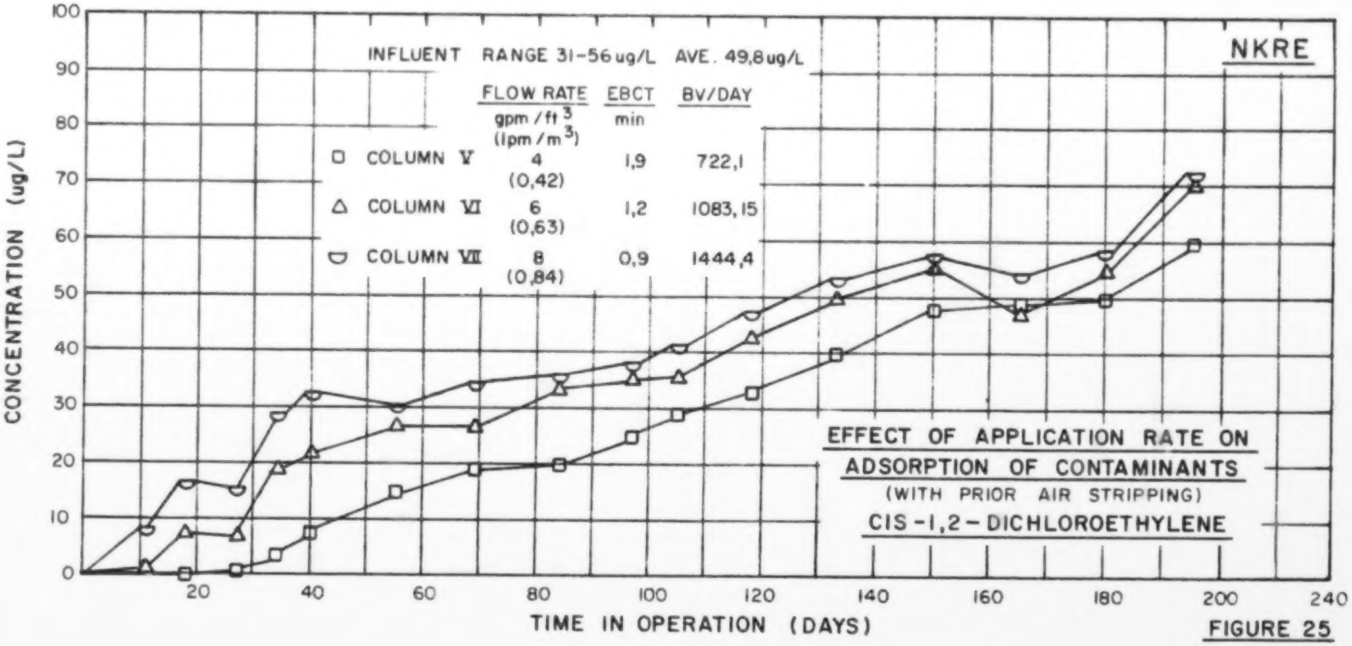
made on May 28 that affected the performance of these columns was the increase of the air:water ratio in the diffused aeration column from 5:1 to 8:1. The rationale for doing this was to lower the individual contaminant levels in the water after diffused aeration as close to the 50 ug/l Guideline limit as possible, thereby lowering the contaminant loadings onto the resin. Since resin columns V, VI and VII were being used to polish the water after aeration, it was surmised that lower contaminant levels in the water being treated in the resin columns would prolong the effective life of the resin. The air:water ratio in the diffused aeration column was increased from 8:1 to 15:1 on July 21, 47 days after the columns were put into operation, when total effluent levels began to exceed 100 ppb, the State Guideline for the sum of all contaminant levels.

Columns V, VI and VII also contained 2 feet (0.61 m) of virgin resin. The application rate for Column V was 4 gpm/ft3 (0.42 Lpm/m3), corresponding to an empty bed contact time (EBCT) of approximately 1.9 minutes or 772.1 bed volumes per day (BV/d). Column VI, oeprating at 6 gpm/ft3 (0.63 Lpm/m3), had an EBCT of 1.2 minutes or 1,083.1 BV/d. Column VII's application rate was 8 gpm/ft3 (0.84 Lpm/m3), corresponding to an EBCT of 0.9 minutes or 1,444.2 BV/d. The columns operated in the countercurrent mode with flow application in the downward direction and steam regeneration in the upward direction.

The performance of resin columns V, VI and VII is depicted on Figures 25 through 28. Similarities can be noted between these curves and those for Columns II, III and IV (Figures 21-24) in the following respects. The slopes of the breakthrough curves for cis-1,2-dichloroethylene at the three application rates used are the greatest of the three major contaminants. While the effluent levels for the cis compound were below the influent levels to the columns for the majority of testing days, the effluent levels at the 6 gpm/ft3 (0.63 Lpm/m3) and 8 gpm/ft3 (0.84 Lpm/m3) rates began to surpass the influent levels toward the latter part of testing. For trichloroethylene and tetrachloroethylene the column effluent levels were less than the influent levels with one exception. This offered further support that cis-1,2-dichloroethylene was least effectively removed by the resin.

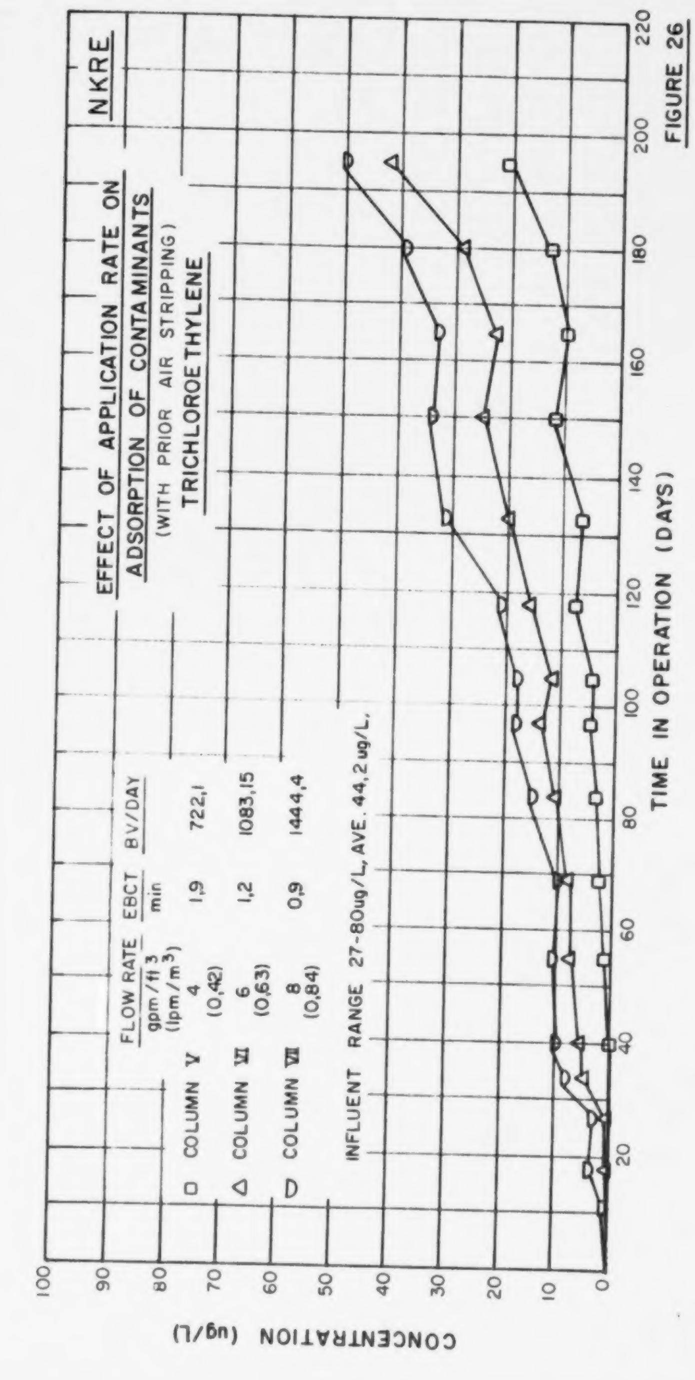
The length of time in service before breakthrough for each of the three major contaminants was longest for Column V (4 gpm/ft3 (0.42 Lpm/m3)) and shortest for Column VII (8 gpm/ft3 (0.84 Lpm/m3)). This was another indication that the rate of resin saturation had a direct relationship to the applied hydraulic loading.

The effect of higher hydraulic loadings on contaminant levels from the columns to which they were applied, followed



EFFECT OF APPLICATION RATE ON ADSORPTION OF CONTAMINANTS
(WITH PRIOR AIR STRIPPING)
CIS-1,2-DICHLOROETHYLENE

FIGURE 25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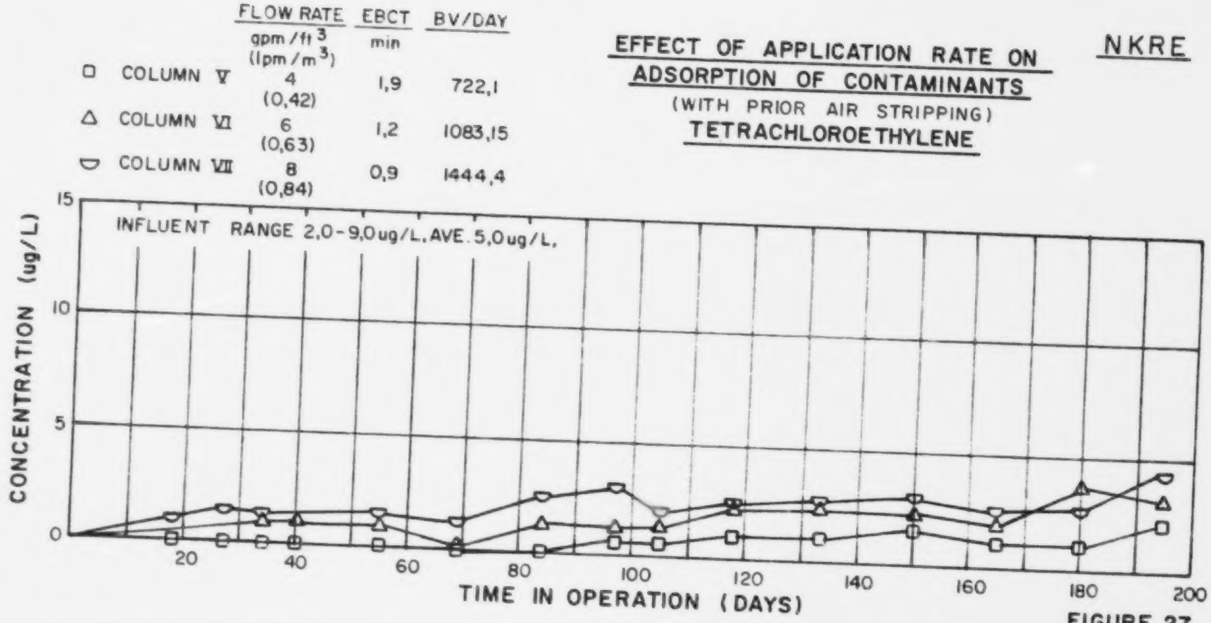
EFFECT OF APPLICATION RATE ON
ADSORPTION OF CONTAMINANTS
(WITH PRIOR AIR STRIPPING)
TRICHLOROETHYLENE
FLOW RATE gpm/ft 3 (lpm/m3)
EBCT min
BV/DAY
□ COLUMN V 4 (0,42) 1,9 722,1
△ COLUMN VI 6 (0,63) 1,2 1083,15
D COLUMN VII 8 (0,84) 0,9 1444,4
INFLUENT RANGE 27-80ug/L, AVE. 44,2 ug/L.
CONCENTRATION (ug/L)
0
10
20
30
40
50
60
70
80
90
100
TIME IN OPERATION (DAYS)
20
40
60
80
100
120
140
160
180
200
220

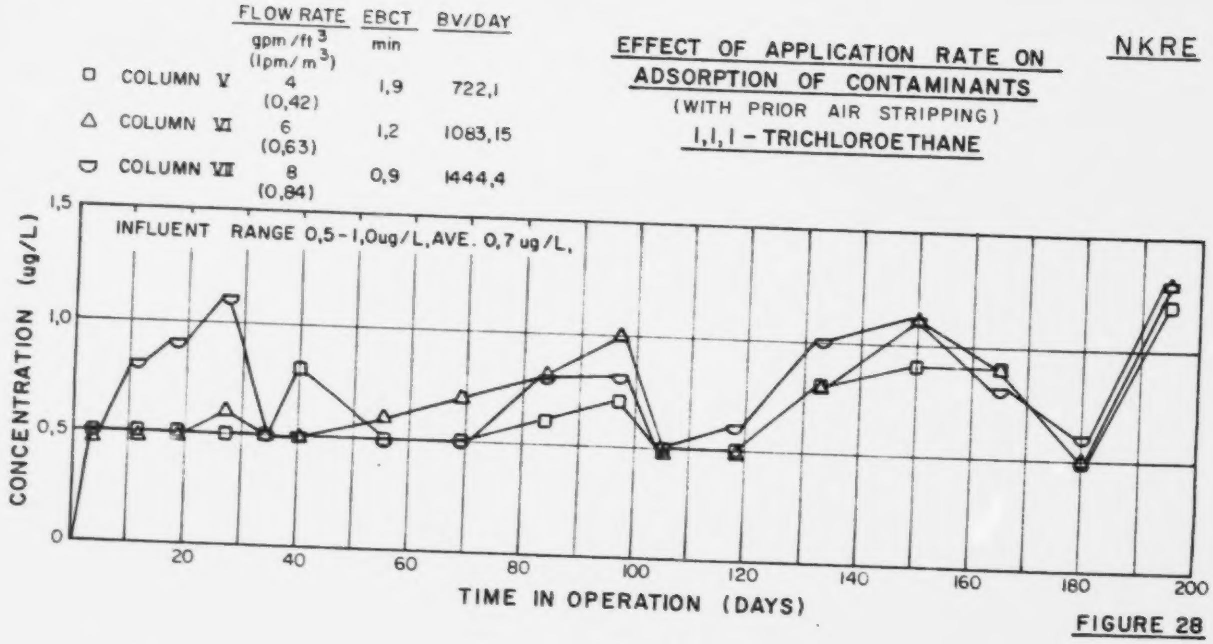
FIGURE 26



EFFECT OF APPLICATION RATE ON ADSORPTION OF CONTAMINANTS (WITH PRIOR AIR STRIPPING) TETRACHLOROETHYLENE

NKRE

FIGURE 27



EFFECT OF APPLICATION RATE ON ADSORPTION OF CONTAMINANTS
(WITH PRIOR AIR STRIPPING)
1,1,1 - TRICHLOROETHANE

NKRE

FIGURE 28

the same trend shown by the columns used for direct treatment of the raw well water. The rate of increase in the effluent levels for the major contaminants was greatest at the 8 gpm/ft3 (0.84 Lpm/m3) application rate, intermediate at the 6 gpm/ft3 (0.63 Lpm/m3) rate, and least for the 4 gpm/ft3 (0.42 Lpm/m3) rate. The saturation and exhaustion properties of the resin, previously observed to have direct relationship to the applied hydraulic loading, were not altered by the lower contaminant levels in the water after aeration. Because of the low levels of 1,1,1-trichloroethane and the gaps in the data points, no discernible patterns were readily evident.

Due to a constant deposition of material on the filter cartridges installed between the diffused aeration column and the resin columns being fed aerated water, the actual flow rates to Columns V, VI and VII were less than the flow rates designated for each column for a major portion of the time these columns were operating. The flow rates that were experienced yielded application rates of 3.6 gpm/ft3 (0.38 Lpm/m3) in Column V, 5.2 gpm/ft3 (0.55 Lpm/m3) in Column VI, and 7.0 gpm/ft3 (0.74 Lpm/m3) in Column VII between start-up and shurt-down of the columns. The application rates specified for the evaluation of the performance of these columns was 4 gpm/ft3, (0.42 Lpm/m3), 6 gpm/ft3 (0.63 Lpm/m3), and 8 gpm/ft3 (0.84 Lpm/m3) for V, VI and VII, respectively. Since the actual application rates are only slightly different from those specified, no changes were made and the actual rate was not considered during evaluation of the data.

The effect of combined treatment, that is aeration followed by resin adsorption, was observed to produce a polished effluent with lower contaminant levels than those produced by aeration or adsorption alone (Figures 29 through 37) for all application rates evaluated. For example, at an application rate of 4 gpm/ft3 (42 Lpm/m3) (Fig. 29), the cis compound reached 50 ug/L in the effluent after 170 days when aeration preceded resin adsorption, but only 30 days with adsorption alone. Similar comparisons for other contaminants and application rates resulted in service times greater than 5 times longer for resin that received aerated water, which translates to a much reduced resin regeneration frequency compared to resin that received raw well water. It was clearly demonstrated that the effective life of the resin would be prolonged by prior aeration of the water.

5. Resin Regeneration

The objective of this portion of the adsorption studies was to continue developing the steam regeneration technique. Only after the regeneration technique for Ambersorb® XE-340 has been fully developed, can its cost-effectiveness for use as an organic contaminant adsorbent for drinking water supplied be defined.

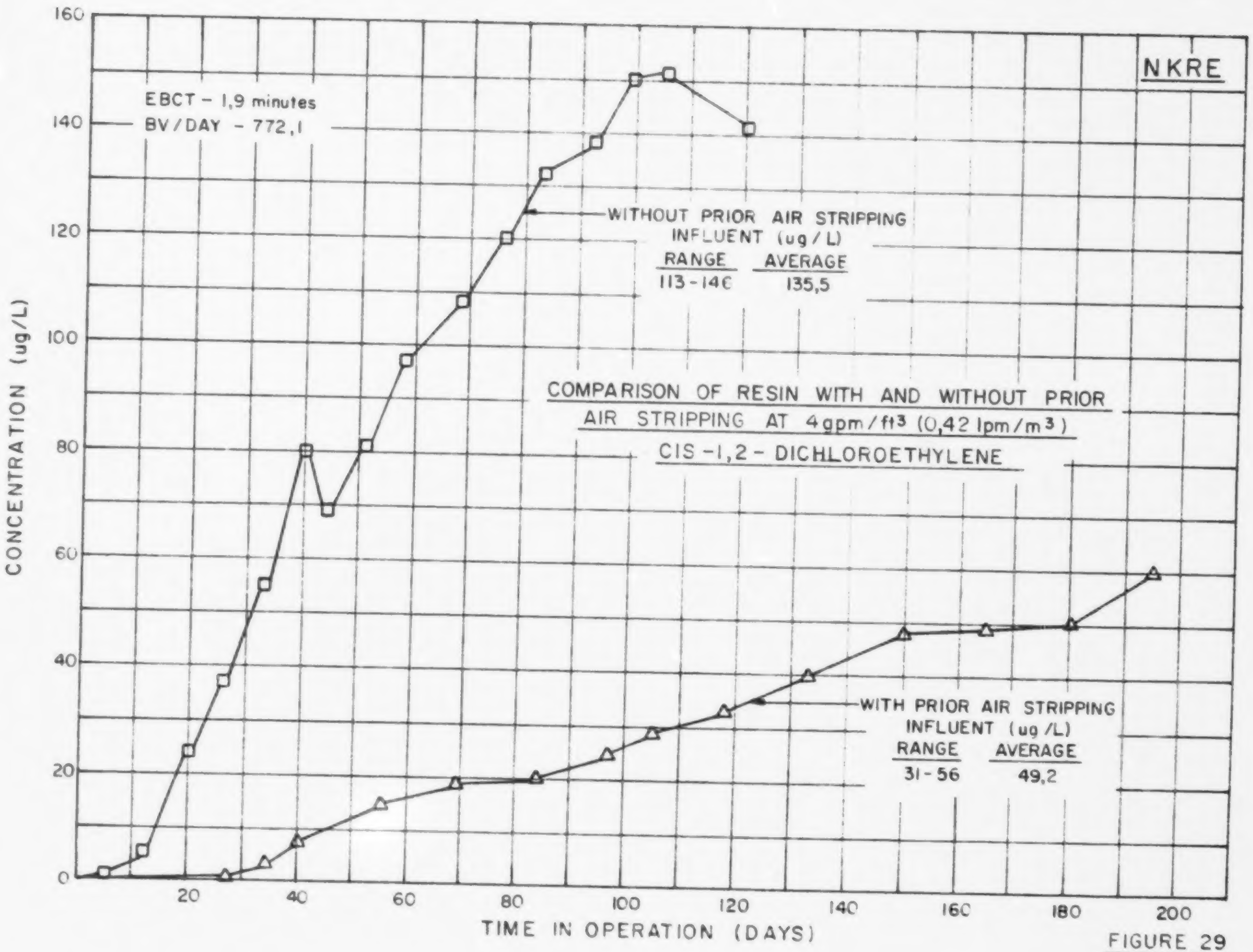

NKRE
EBCT - 1,9 minutes
BV/DAY - 772,1
WITHOUT PRIOR AIR STRIPPING
INFLUENT (ug/L)
RANGE AVERAGE
113-146 135,5
COMPARISON OF RESIN WITH AND WITHOUT PRIOR
AIR STRIPPING AT 4gpm/ft3 (0,42 lpm/m3)
CIS-1,2-DICHLOROETHYLENE
WITH PRIOR AIR STRIPPING
INFLUENT (ug/L)
RANGE AVERAGE
31-56 49,2
CONCENTRATION (ug/L)
0
20
40
60
80
100
120
140
160
TIME IN OPERATION (DAYS)
20
40
60
80
100
120
140
160
180
200

FIGURE 29

COMPARISON OF RESIN WITH AND WITHOUT PRIOR AIR STRIPPING AT 4 gpm/ft³ (0,42 lpm/m³)

TRICHLOROETHYLENE

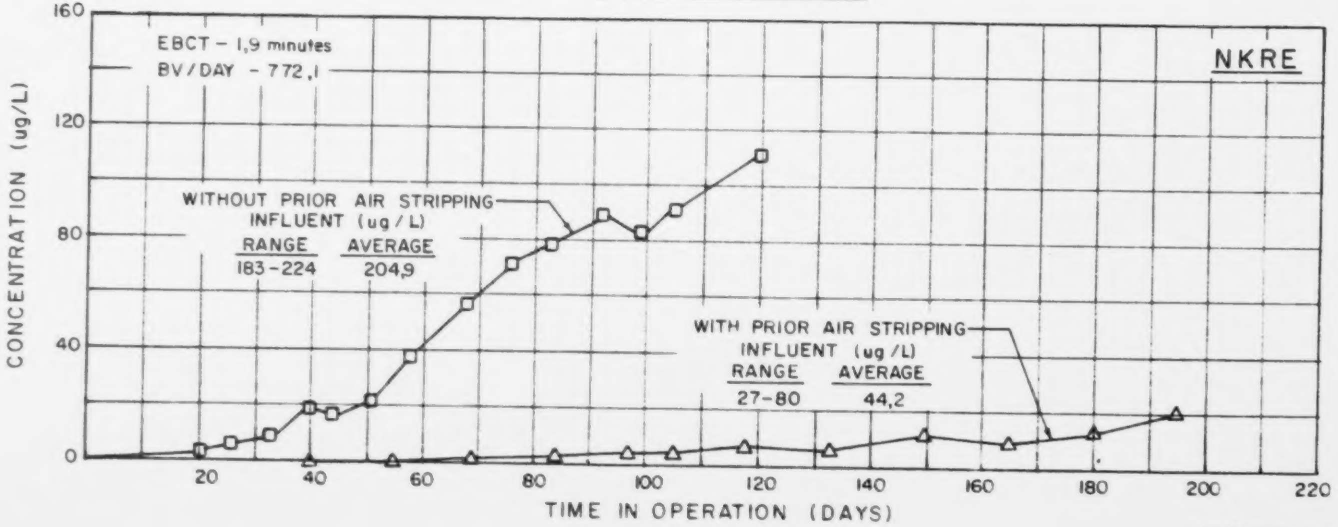


FIGURE 30

COMPARISON OF RESIN WITH AND WITHOUT PRIOR AIR STRIPPING AT 4gpm/ft^3 (0,42 lpm/m^3)

TETRACHLOROETHYLENE

NKRE

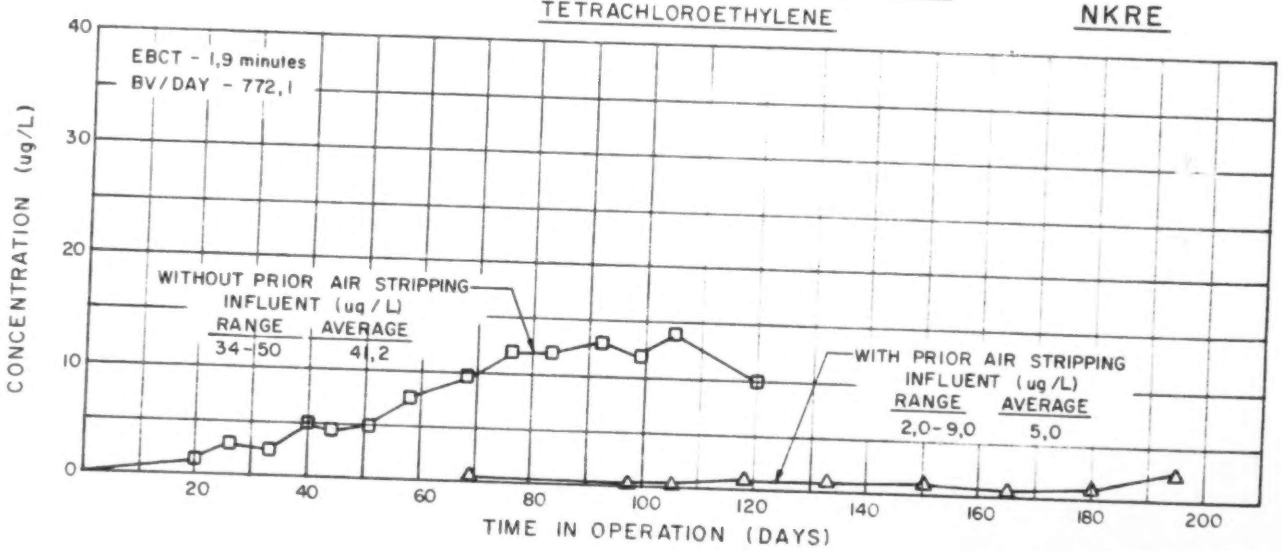


FIGURE 31

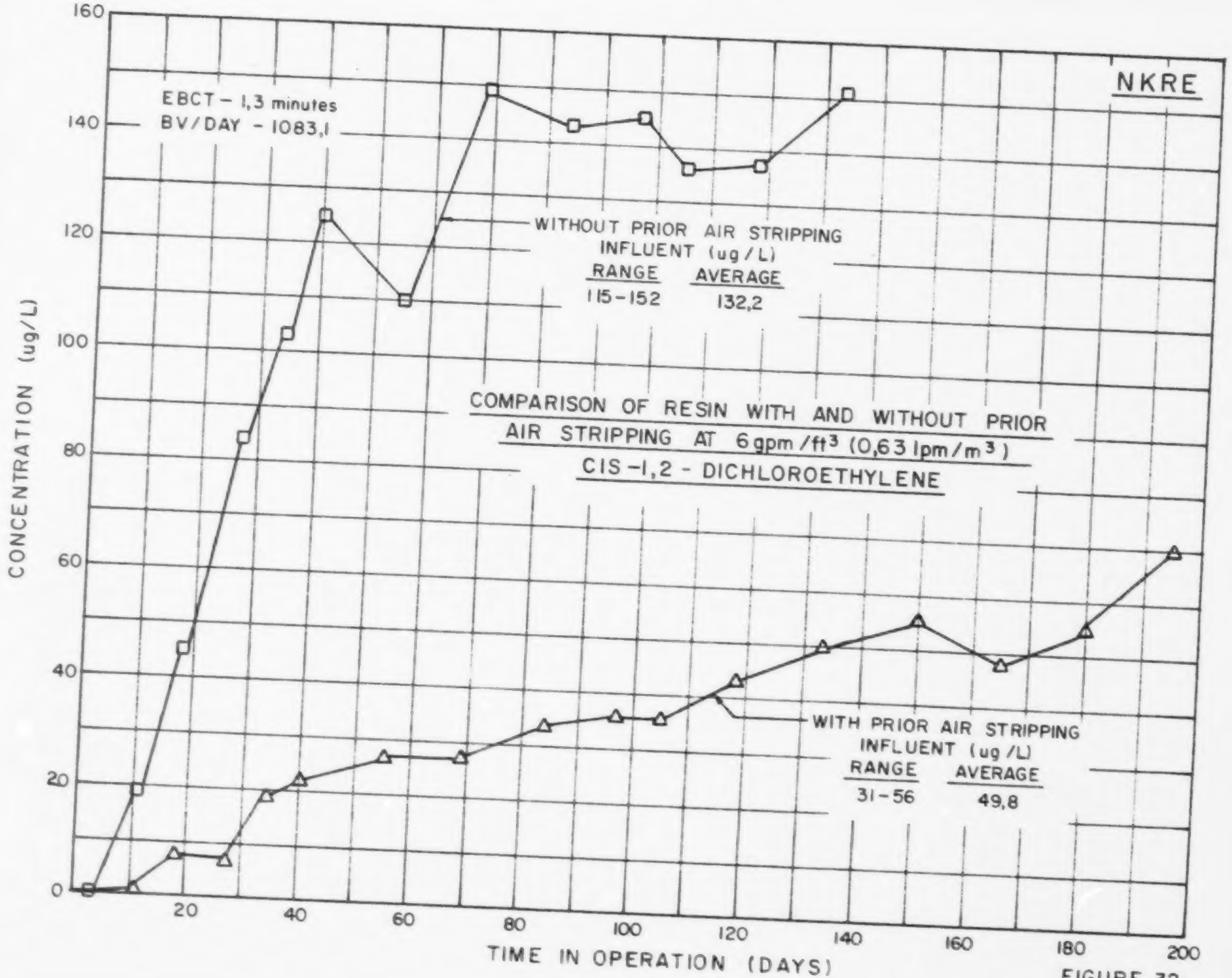
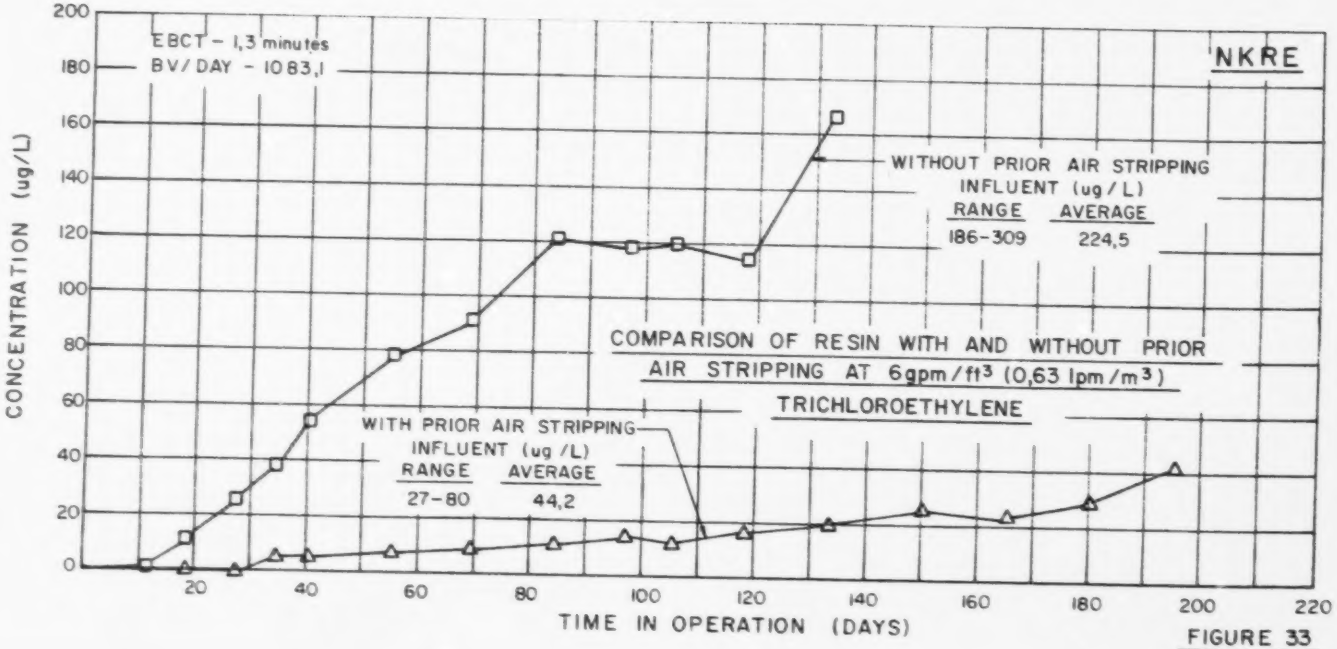

NKRE
EBCT - 1,3 minutes
BV/DAY - 1083,1
WITHOUT PRIOR AIR STRIPPING
INFLUENT (ug/L)
RANGE AVERAGE
115-152 132,2
COMPARISON OF RESIN WITH AND WITHOUT PRIOR
AIR STRIPPING AT 6 gpm/ft³ (0,63 lpm/m³)
CIS-1,2 - DICHLOROETHYLENE
WITH PRIOR AIR STRIPPING
INFLUENT (ug/L)
RANGE AVERAGE
31-56 49,8
CONCENTRATION (ug/L)
0
20
40
60
80
100
120
140
160
TIME IN OPERATION (DAYS)
20
40
60
80
100
120
140
160
180
200

FIGURE 32



COMPARISON OF RESIN WITH AND WITHOUT PRIOR AIR STRIPPING AT 6gpm/ft³ (0,63 lpm/m³)

TRICHLOROETHYLENE

FIGURE 33

NKRE

COMPARISON OF RESIN WITH AND WITHOUT PRIOR AIR STRIPPING AT 6 gpm/ft³ (0,63 lpm/m³)

TETRACHLOROETHYLENE

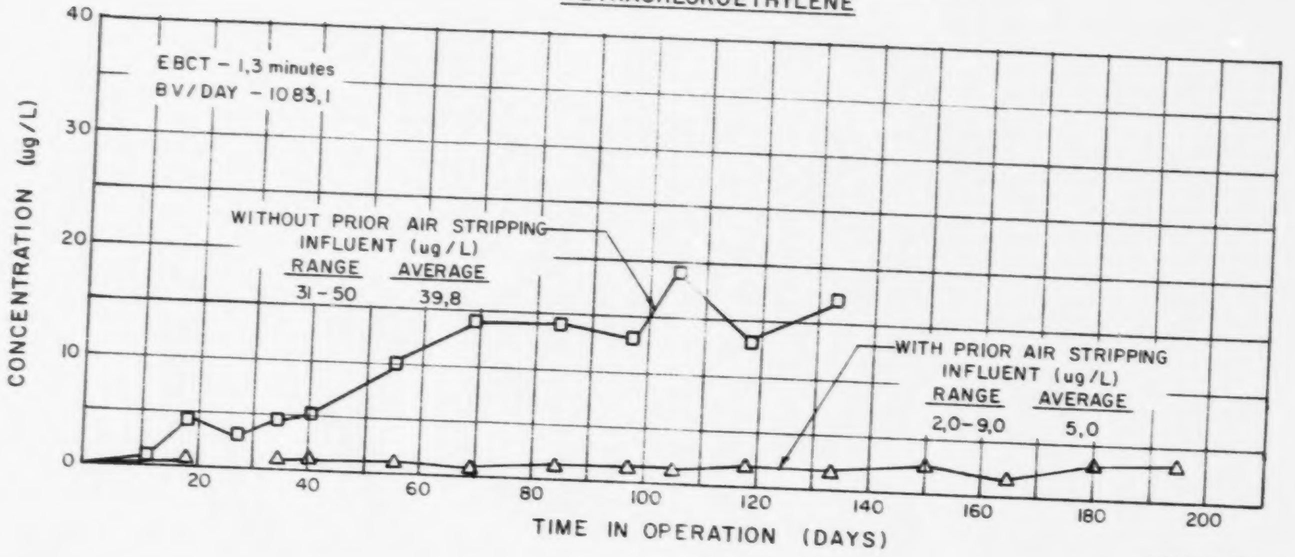
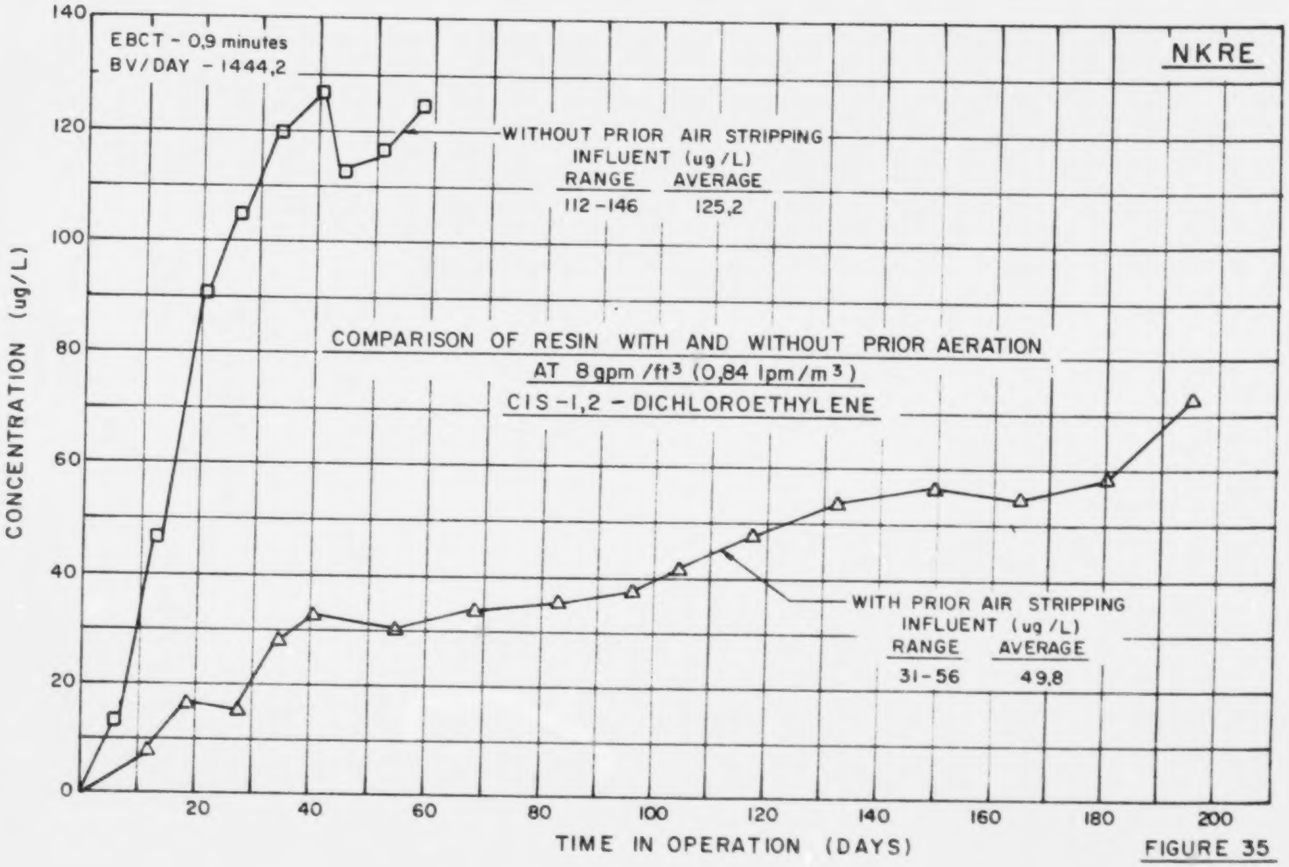


FIGURE 34



COMPARISON OF RESIN WITH AND WITHOUT PRIOR AERATION

AT 8 gpm/ft³ (0,84 lpm/m³)

CIS-1,2 - DICHLOROETHYLENE

FIGURE 35

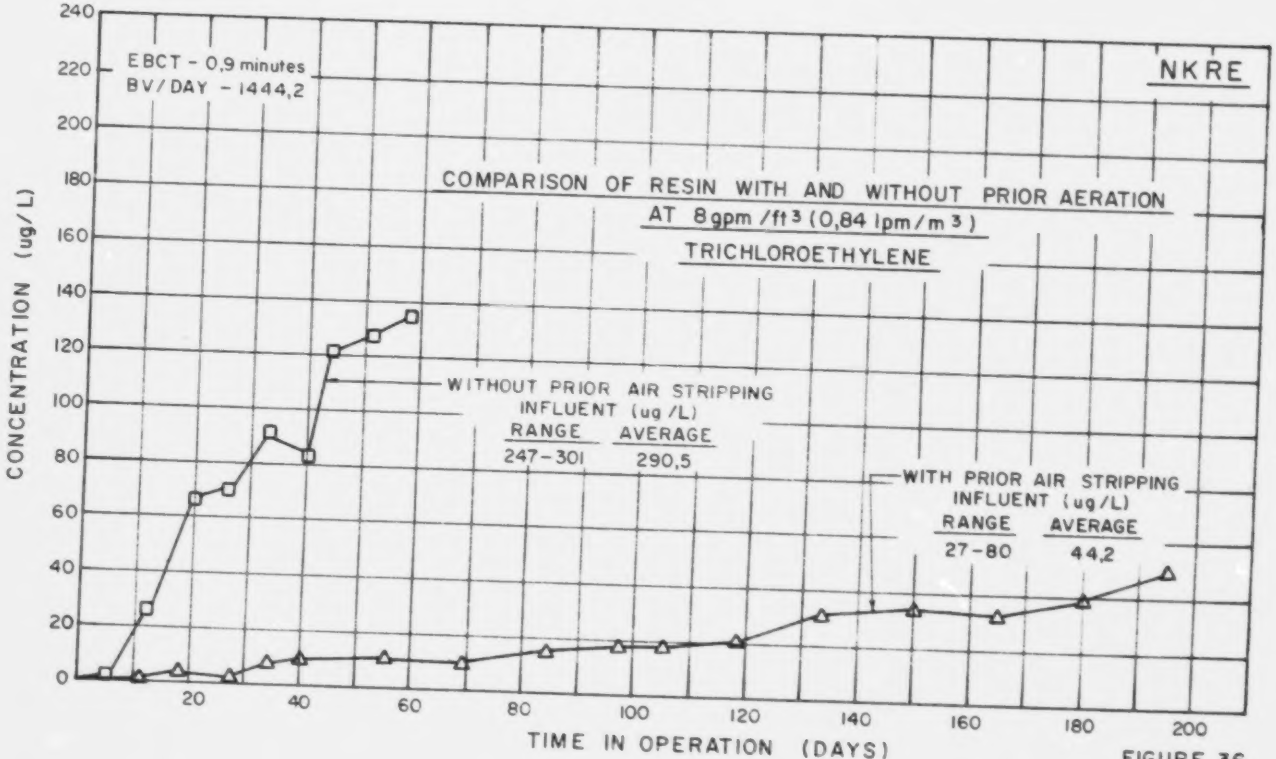

EBCT - 0,9 minutes
BV/DAY - 1444,2
NKRE
COMPARISON OF RESIN WITH AND WITHOUT PRIOR AERATION
AT 8 gpm /ft3 (0,84 lpm/m3)
TRICHLOROETHYLENE
WITHOUT PRIOR AIR STRIPPING
INFLUENT (ug/L)
RANGE AVERAGE
247-301 290,5
WITH PRIOR AIR STRIPPING
INFLUENT (ug/L)
RANGE AVERAGE
27-80 44,2
CONCENTRATION (ug/L)
240
220
200
180
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
200
TIME IN OPERATION (DAYS)

FIGURE 36

NKRE

COMPARISON OF RESIN WITH AND WITHOUT PRIOR AERATION
AT 8 gpm /ft³ (0,84 lpm / m³)
TETRACHLOROETHYLENE

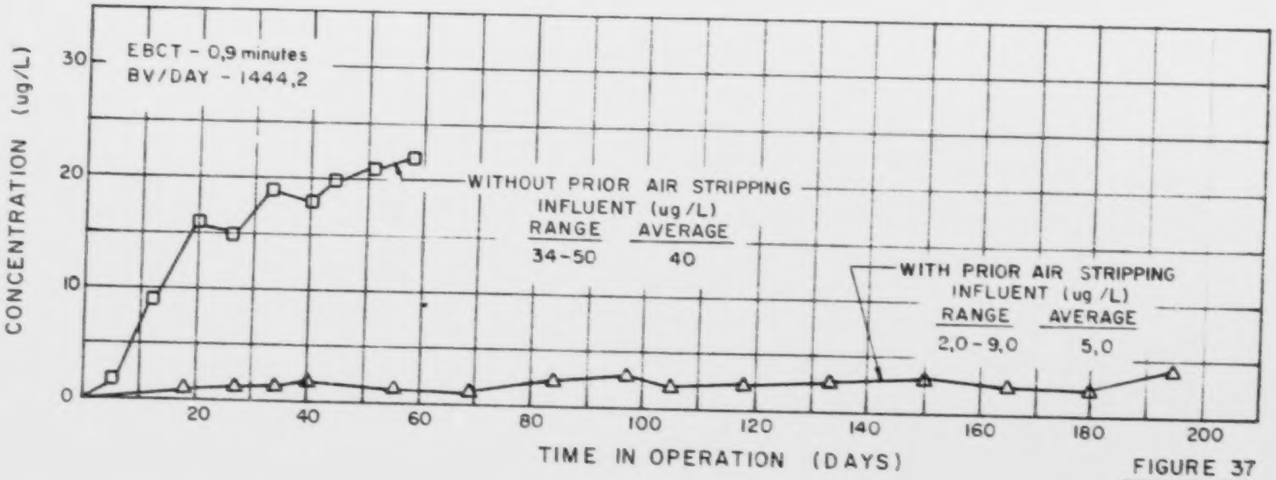


FIGURE 37

Improvements made to enhance the degree of regeneration in Phase II resulted in more successful regenerations than those attempted in Phase I. These improvements are described in Section 4 of the Phase II report, and the procedure followed in conducting a regeneration cycle is outlined in the Phase I report.

Because the first 7 1/2 months of the resin testing portion of Phase III was performed using unacceptable resin, the scope of the regeneration studies during Phase III was not treated as thoroughly as originally intended. Further refinement of the steam regeneration technique with regard to optimization of the amount of steam required and proper handling and disposal of the steam condensate were not possible due to the limited number of regenerations needed while the acceptable resin was in service.

Column II, on line at 4 gpm/ft3 (0.42 Lpm/m3), was regenerated from 8/3/82 to 8/4/82. The column, which received raw well water from Well #22, was in service for 124 days before it was regenerated. The last day the column was sampled (the 120th day of its operation) prior to regeneration, the total effluent contaminant level from the column was 266 ppb.

The information pertaining to this regeneration is presented in Table 6. The regeneration was conducted for 12 hours, during which time 18 bed volumes of steam were used to strip contaminants from the resin. The direction of steam flow was countercurrent to the applied water flow so that the stripped contaminants had to pass by occupied sites in the upper portions of the resin allowing the regeneration to proceed more quickly and efficiently. Because the resin was virgin at the start of its first cycle and it was not superloaded (discussed in the Regeneration Section of the Phase II report), the only organic contaminant loading it experienced was a result of the 93,340 bed volumes of water which had passed through the column during the 124 days it had been in service. The percentage removal, defined as the ratio of total organics removed to total organics loaded times 100, was 50%.

Figures 38 through 40 compare the performance of virgin versus regenerated resin for Column II for cis-1,2-dichloroethylene, tri-, and tetra-chloroethylene. The contaminant removal efficiency of Column II's regenerated resin was better than that of the virgin resin up to the 42nd day for cis-1,2-dichloroethylene and up to the 83rd day for trichloroethylene. For tetrachloroethylene the effluent levels for the virgin and regenerated resin very nearly duplicated one another for the first 45 days, while increased removal efficiency was indicated for the regenerated resin between the 80th and the 115th day.

TABLE 6

GLEN COVE, N.Y. - PILOT PLANT - PHASE III

RESIN COLUMN REGENERATION

SUMMARY OF RESULTS

	Column II	Column IV
Composition	Rohm & Haas Ambersorb® XE-340 virgin	Rohm & Haas Ambersorb® XE-340 virgin
Resin Bed Volume (liters)	5	5
Direction of Water Flow	Down	Down
Direction of steam	Up	Up
Regeneration		
Dates	8/3-8/4/82	11/1-11/2/82
Calculated Bed Volumes of Water Passed until Regeneration	93,340	157,477
Bed Volumes of Steam Used	18	24½
Loading - carryover (g)*	-	-
Organics in Water (g)**	101.2	118.7
Superloading (g)***	-	24.1
Total Loading (g)	101.2	142.8
Organics Removed - Aqueous Phase (g)	25.5	40.2
Estimated Volume - Organic Phase (ml)	23.0	22.0
Mass of Organic Phase (g)	34.3	32.8
Total Removed (g)	59.8	73.0
Organics Remaining (g)	41.4	69.8
Percentage Regeneration ****	59 %	51 %

---

* Organics remaining in resin after previous regeneration

** Organics removed from water during run prior to regeneration

*** Organics placed in resin due to superloading procedure

**** Percentage regeneration = $\frac{\text{Total Removal}}{\text{Total Loading}} \times 100$

COMPARISON OF VIRGIN VERSUS REGENERATED RESIN

CIS-1,2 - DICHLOROETHYLENE

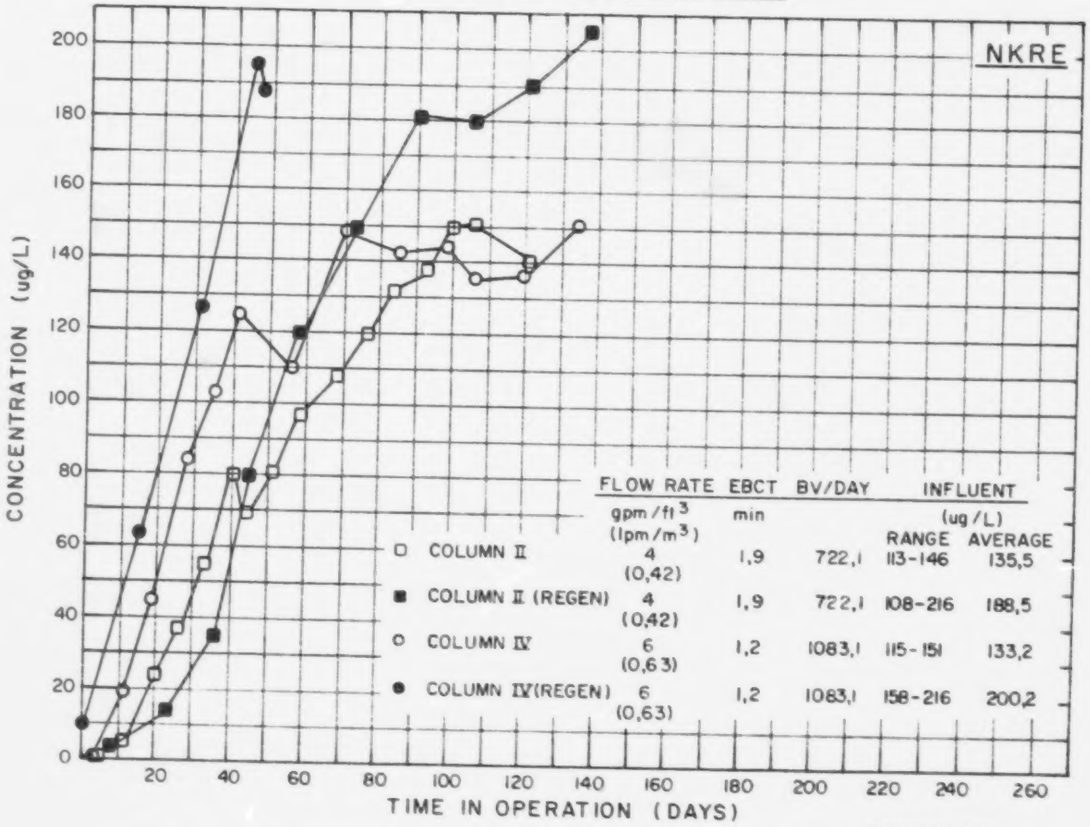


FIGURE 38

COMPARISON OF VIRGIN VERSUS REGENERATED RESIN
TRICHLOROETHYLENE

	FLOW RATE gpm/ft 3 (lpm/m3)	EBCT min	BV/DAY	INFLUENT (ug/L) RANGE	INFLUENT (ug/L) AVERAGE
□ COLUMN II	4 (0,42)	1,9	722,1	183-224	204,9
■ COLUMN II (REGEN)	4 (0,42)	1,9	722,1	183-309	236,1
○ COLUMN IV	6 (0,63)	1,2	1083,1	186-222	205,6
● COLUMN IV (REGEN)	6 (0,63)	1,2	1083,1	247-301	290,5

NKRE

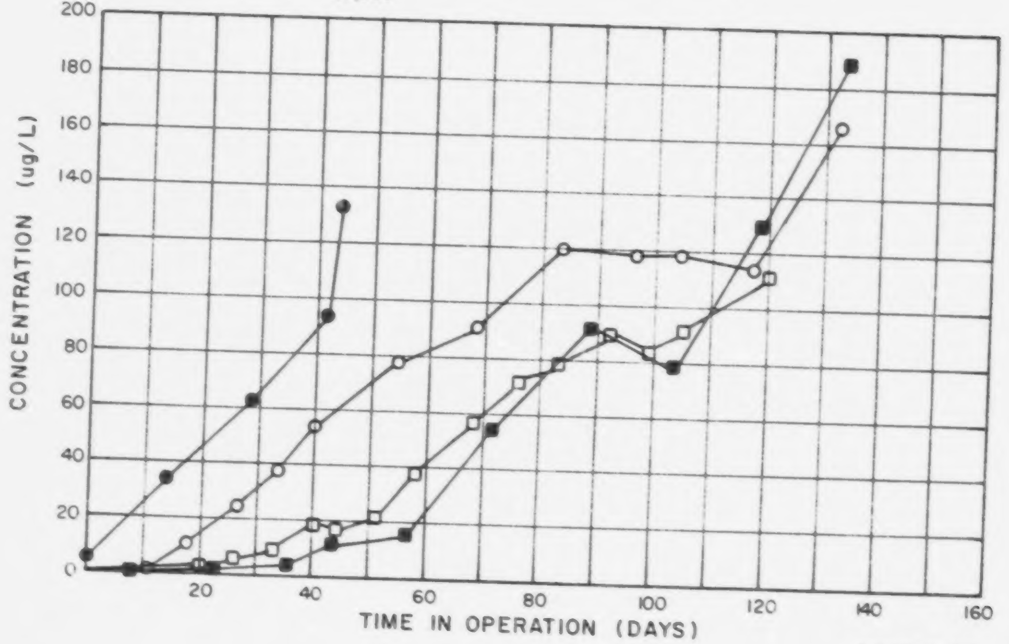


FIGURE 39

COMPARISON OF VIRGIN VERSUS REGENERATED RESIN
TETRACHLOROETHYLENE

NKRE

	FLOW RATE gpm/ft^3 (lpm/m^3)	EBCT min	BV/DAY	INFLUENT (ug/L) RANGE	INFLUENT (ug/L) AVERAGE
□ COLUMN II	4 (0,42)	1,9	722,1	34-50	41,2
■ COLUMN II (REGEN)	4 (0,42)	1,9	722,1	31 - 46	37,8
○ COLUMN IV	6 (0,63)	1,2	1083,1	31-50	39,5
● COLUMN IV (REGEN)	6 (0,63)	1,2	1083,1	38-45	40,8

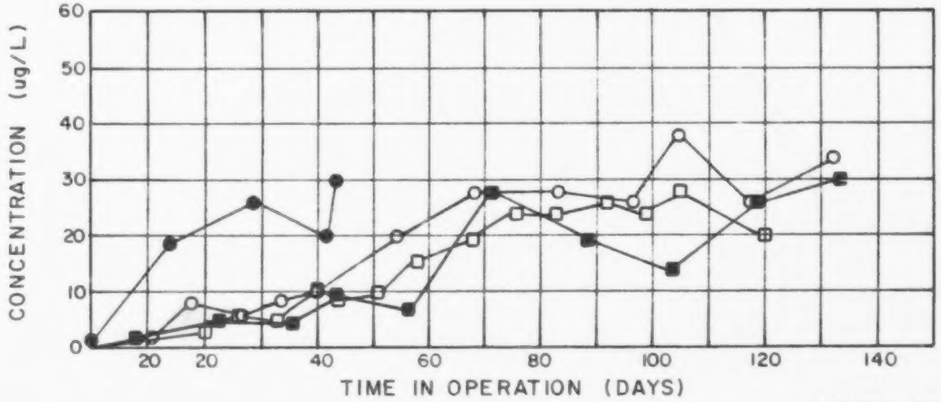


FIGURE 40

The reason for the improved performance of the regenerated resin over that of the virgin resin between days 80 and 115 of column operation is unknown but possibly the result of the slightly lower influent tetrachloroethylene concentrations that were seen by the resin during the second cycle (regenerated resin).

Column IV, operating at 6 gpm/ft3 (0.63 Lpm/m3), was regenerated from 11/1/82 to 11/2/82. This column also received raw well water from Well #22, and its length of time in service prior to regeneration was 149 days. The last sample taken from the column before it was regenerated showed a 339 ppb total contaminant level in the effluent from the column.

Before the regeneration of the resin was begun, the column was "superloaded" with 24 gallons of condensate from the regeneration of Column I which had been performed immediately before Column IV's regeneration. The purpose of "superloading" or introducing the condensate obtained from the regeneration of one column into another column about to be regenerated, is to minimize the amount of condensate which ultimately will require disposal. If the regeneration of the "superloaded" resin is successful, a larger organic phase should appear in the condensate due to the large amount of organics present in the "superloaded" resin. The handling and safe disposal of the organic phase could proceed more expeditiously than that of the large volumes of condensate produced by a regeneration.

In addition to the 118.7 g of organics which had been loaded onto the resin as a result of the 157,477 bed volumes of water which had passed through the column prior to its regeneration, 24.1 g contained in the condensate from Column I were "superloaded" which produced a total loading of 142.8 g. The regeneration was carried out for 13 1/2 hours during which time 24 1/2 bed volumes of steam were applied countercurrently to the direction of water flow. The resulting regeneration efficiency was only 51 percent.

As can be seen from Figures 38, 39, and 40, the contaminant removal efficiency of the regenerated resin was never better than that of the virgin resin for any of the three major contaminants. There are several factors responsible for the lower adsorptive capacity exhibited by the regenerated resin. The regeneration was successful at removing slightly more than half the contaminants which had been loaded onto the resin during its first cycle and from "superloading". This meant that half the sites which had been available for contaminant adsorption in the virgin resin were occupied in the regenerated resin. Because of this reduction in the number of sites for adsorption to take place, the performance of the regenerated resin could not be expected to be as efficient as the virgin resin.

Another factor contributing to the higher effluent levels seen from the regenerated resin was the higher average influent levels for the three major contaminants that were experienced during the second cycle. For cis-1,2-dichloroethylene and trichloroethylene, the average influent concentration to the regenerated resin, respectively, was 67.0 ppb and 84.9 ppb greater than to the virgin resin. The average influent concentration to the regenerated resin was 1.3 ppb greater than to the virgin resin for tetrachloroethylene. Undoubtedly, the combined effect of the 51 percent regeneration of the resin and the higher average influent concentrations to the resin during the second cycle caused the lower removal efficiencies that were observed for the regenerated resin.

On Figures 38 and 39 it is shown that the breakthrough curves for the regenerated resin parallel those of the virgin resin for the first 40 days for cis-1,2-dichloroethylene and for 42 days for trichloroethylene. Although the effluent levels from the regenerated resin are somewhat higher than those for the virgin resin, the similar removal patterns displayed by the two resins relates to the degree of success of the regeneration. While there was a significant improvement in resin performance after the regeneration, contaminant removal was more effective by the virgin resin.

6. Summary

The primary objectives of the Phase III resin adsorption studies were to evaluate a combined aeration-adsorption treatment system scheme, to determine the optimum hydraulic loading rate for the resin, and to further develop the steam regeneration technique. The first two objectives were adequately assessed while acceptable resin was being utilized during the latter part of the original and the extended portion of the testing program. Because of the lower hydraulic loading rates being applied to the resin columns, a limited number of regenerations were required, hindering further improvement of the steam regeneration technique.

The combined aeration-adsorption treatment studies conclusively demonstrated that a polished effluent capable of meeting existing drinking water guidelines was produced by first aerating the water to reduce contaminant levels and subsequent treatment by resin adsorption. The improvement in the removal efficiencies of the resin when aerated versus when raw water was applied to the columns can be readily observed in Figures 29 through 37.

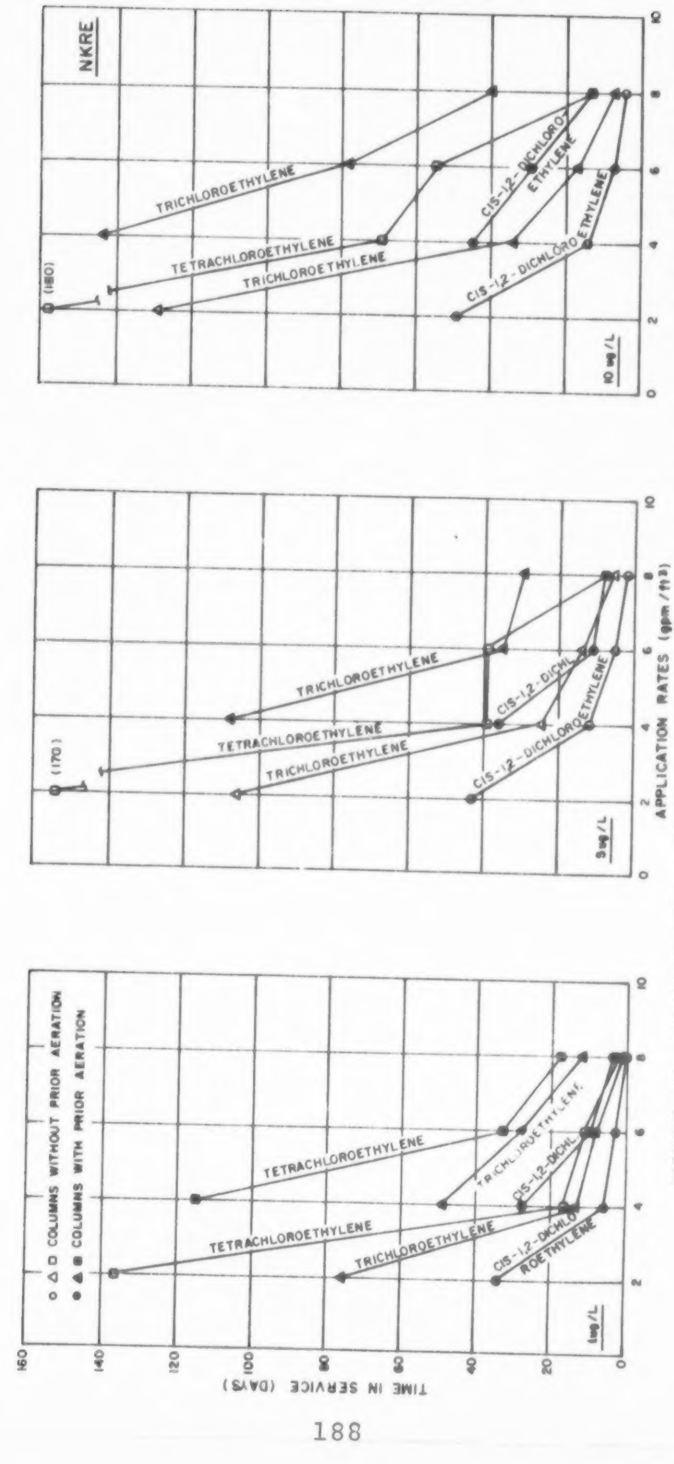
Performance of the resin with and without prior aeration was compared at application rates of 4 gpm/ft3 (0.42 Lpm/m3), 6 gpm/ft3 (0.63 Lpm/m3), and 8 gpm/ft3 (0.84 Lpm/m3).

Contaminant levels for the three major contaminants in the column effluents indicated that the rates of resin saturation and exhaustion had a direct relationship to the applied hydraulic loading in both instances, that is, with and without prior aeration of the water.

Another point indicated on these graphs is the greater lengths of service time for the resin columns receiving water after aeration. The service times were more favorable in regard to contaminant removal efficiencies at the lowest (4 gpm/ft3 - 0.42 Lpm/m3) application rate, and least favorable at the highest (8 gpm/ft3 - 0.84 Lpm/m3) rate. The increased service times were due to the lower contaminant loadings onto the resin from the aerated water. At the 8:1 and 15:1 air:water ratios that were used to strip contaminants from the water prior to treatment by the resin, the regeneration frequency for the columns receiving aerated water would have been at least 5 times less than their counterparts receiving raw water at the 4, 6, and 8 gpm/ft3 (0.42, 0.63, and 0.83 Lpm/m3) rates. Thus, in the process of producing a polished effluent by aerating the water prior to resin treatment, lower contaminant loadings to the resin increase its effective life.

Figure 41 displays the variance of service time required to achieve specified breakthrough levels at the various application rates tested. Service times needed to reach effluent levels of 1, 5 and 10 ug/L for each of the major contaminants are shown for the following application rates: 2 gpm/ft3 (0.21 Lpm/m3) (without aeration), 4 gpm/ft3 (0.42 Lpm/m3) (with and without aeration), 6 gpm/ft3 (0.63 Lpm/m3) (with and without aeration) and 8 gpm/ft3 (0.84 Lpm/m3) (with and without aeration). Conclusive proof is shown of the direct relationship between the application rate and rate of resin saturation, as demonstrated by the length of time to reach the 1, 5, or 10 ug/L level. The fact that the resin is most effective at removing tetrachloroethylene and least effective at removing cis-1,2-dichloroethylene at all of the application rates used is also observed, as are the improved contaminant removal efficiencies noted in the resins receiving aerated water. The usefulness of these graphs would be realized in the selection of an optimum hydraulic loading rate once a desired target level for contaminant concentration has been established. It should be remembered that for the points on the graphs corresponding to effluents from columns in the combined aeration-adsorption system, an air:water ratio of 15:1 was used.

The different application rates to the direct (2, 4, 5, and 8 gpm/ft3 (0.21, 0.42, 0.63, and 0.84 Lpm/m3)) and the combined aeration-adsorption (4, 6, and 8 gpm/ft3 (0.42, 0.63, and 0.84 Lpm/m3)) treatment systems were utilized to determine the optimum hydraulic loading for the resin.



VARIANCE WITH APPLICATION RATE OF SERVICE TIME TO ACHIEVE BREAKTHROUGH LEVELS OF THE CONTAMINANTS

FIGURE 41

For the direct treatment resin system, the service times to achieve the same effluent concentration for the various contaminants at the different hydraulic loading has a relationship to the hydraulic loading. In general, the service time to achieve a target level of contaminant increased by 3 times as the hydraulic loading was reduced. The actual hydraulic loading on the resin must be evaluated as a function of economics which should be based on the service time to achieve a required level of contamination in the effluent.

When evaluating the various hydraulic loadings for a combined aeration-adsorption treatment system as a function of service time for a target contaminant level, again a relationship between service time and hydraulic loading is present. The service time to achieve a target level of contaminant increased by at least a factor of 1.5 as the hydraulic loading was reduced. As was the case for the direct resin treatment system the decision as to the optimum hydraulic loading for the resin portion of a combined aeration-adsorption treatment system must be determined as a function of economics.

Resin regeneration conducted during Phase III demonstrated that, although resin performance was improved by regeneration, restoration to 100 percent of its virgin adsorbent capacity did not take place. Regenerations carried out during Phase III restored only about 59 percent to 51 percent of the adsorbent capacity to the resin columns which were regenerated. The reason for the lower percent regenerations during this phase than Phase II is not clear. Since development of the regeneration process is critical for a resin treatment system to which raw well water is applied, further refinement of this technology is indicated.

The observation that was made during Phases I and II that the order of contaminants' saturation and breakthrough for the resin was cis-1,2-dichloroethylene, trichloroethylene and then tetrachloroethylene was confirmed during Phase III.

C. GRANULAR ACTIVATED CARBON COLUMN TESTING

The granular activated carbon column (GAC) installed in Phase III was to study the movement or wave front of the various contaminants through the activated carbon bed. The GAC column, which was 6 ft (1.83 m) high and 4 inches (0.10 m) in diameter, contained 4 ft (1.22 m) of Calgon GAC and sample taps at each 1 ft (0.31 m) depth of media. The system was operated at 21 gph (79.5 Lph) producing a seven (7) minute empby bed contact time. The column operation started on January 13, 1982, and continued to the end of the Phase III field study period.

Sampling and analyses were performed initially for the influent and the sampling tap at the first foot (0.31 m) tap. As contamination appeared to saturate the first sample tap the next lower tap was added to the sampling sequence. This procedure was continued until all four sample taps were included. The data developed during the Phase III program is presented in Appendix D and presented graphically in Figures 42 through 45.

Table 7 presents the time in days required to achieve concentration levels for each of the four contaminants; cis-1,2-dichloroethylene, trichloroethylene, tetrachloroethylene and 1,1,1-trichloroethane. Also presented on Table 7 is a computed time in days per foot per ug/L of each contaminant. The data indicates that cis-1,2-dichloroethylene penetrates the carbon bed at the fastest rate, requiring 0.15 days per ft (30.5 cm) per ug/L of contaminant, and 1,1,1-trichloroethane is the slowest in penetration, requiring 16.2 days per ft per ug/L of contaminant. The values for trichloroethylene range from 0.35 to 0.76 days per ft (30.5 cm) per ug/L of contaminant and tetrachloroethylene range from 0.3 to 15.6 days per ft per ug/L of contaminant. It was not possible to study more than one concentration for cis-1,2-dichloroethylene due to the rapid movement, and for 1,1,1-trichloroethane due to the low influent concentration.

When studying the graphical presentation of the data it is evident that desorption or slough-off occurs when the concentration at the sampling tap equals or exceeds the concentration in the influent to the test column. This is particularly true for cis-1,2-dichloroethylene, but is also present for trichloroethylene and 1,1,1-trichloroethane. It was not possible to determine if desorption occurs for tetrachloroethylene since its concentration at any sample tap never exceeded the influent concentration. This contaminant movement should be studied for various granular activated carbons and at several empty bed contact times.

NKRE

CONTAMINANT MOVEMENT THROUGH 4 ft (1,22 m) OF ACTIVATED CARBON
CIS-1,2-DICHLOROETHYLENE

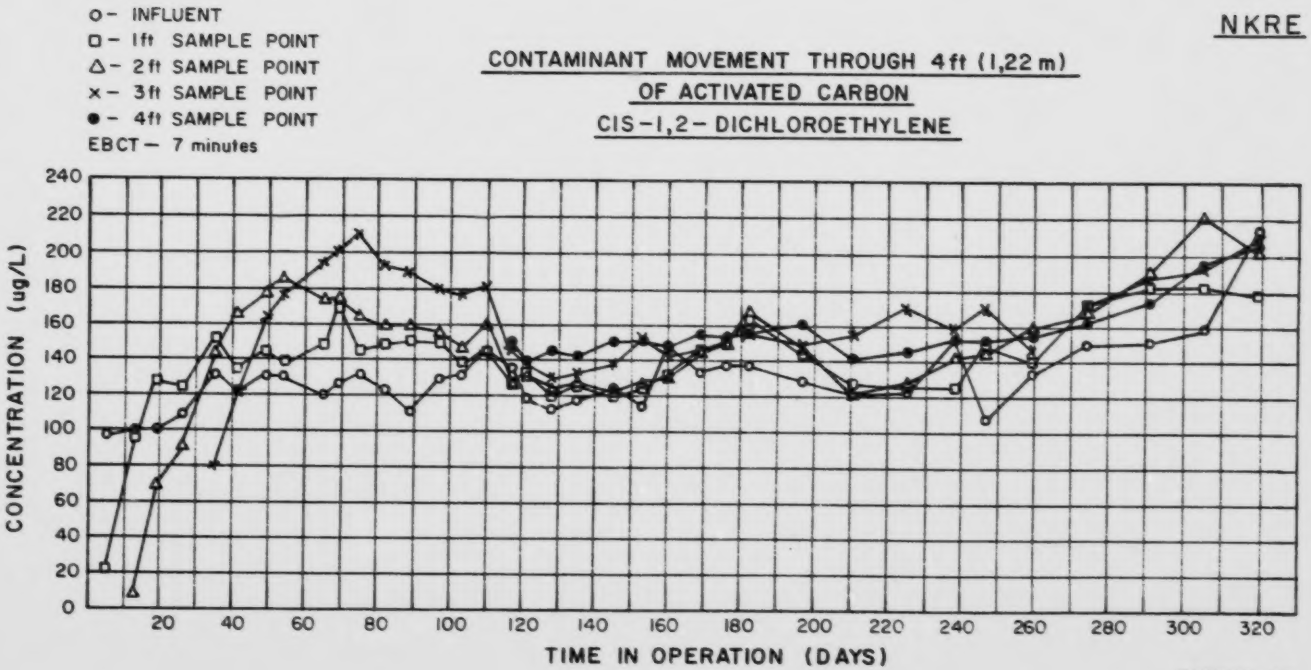


FIGURE 42

NKRE

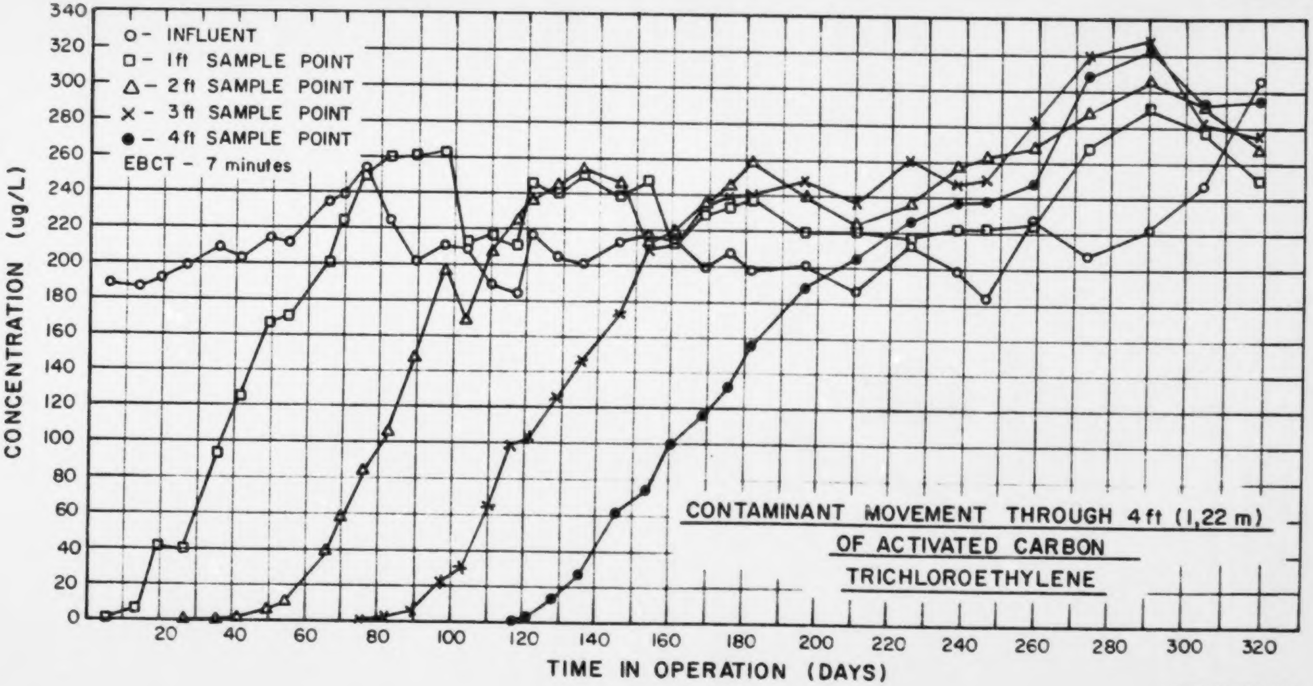


FIGURE 43

NKRE

CONTAMINANT MOVEMENT THROUGH 4ft (1,22 m) OF ACTIVATED CARBON

TETRACHLOROETHYLENE

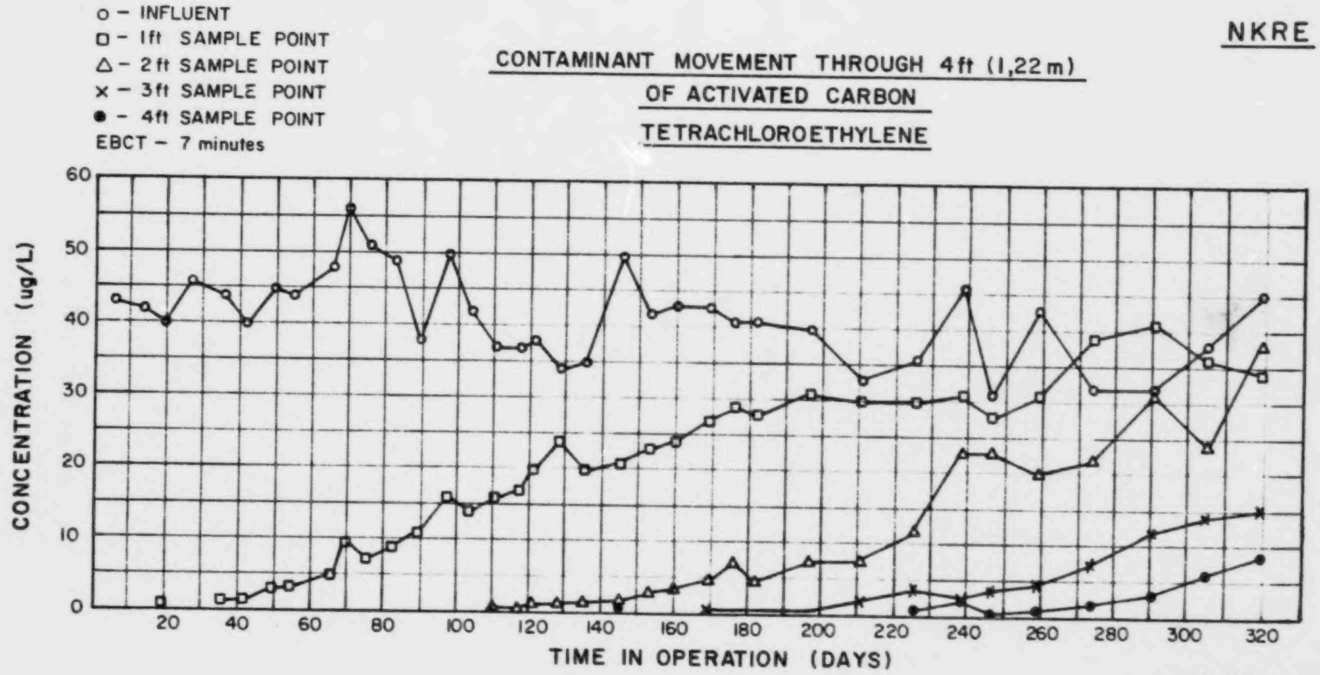


FIGURE 44

NKRE

CONTAMINANT MOVEMENT THROUGH 4ft (1,22 m)
OF ACTIVATED CARBON
1,1,1 - TRICHLOROETHANE

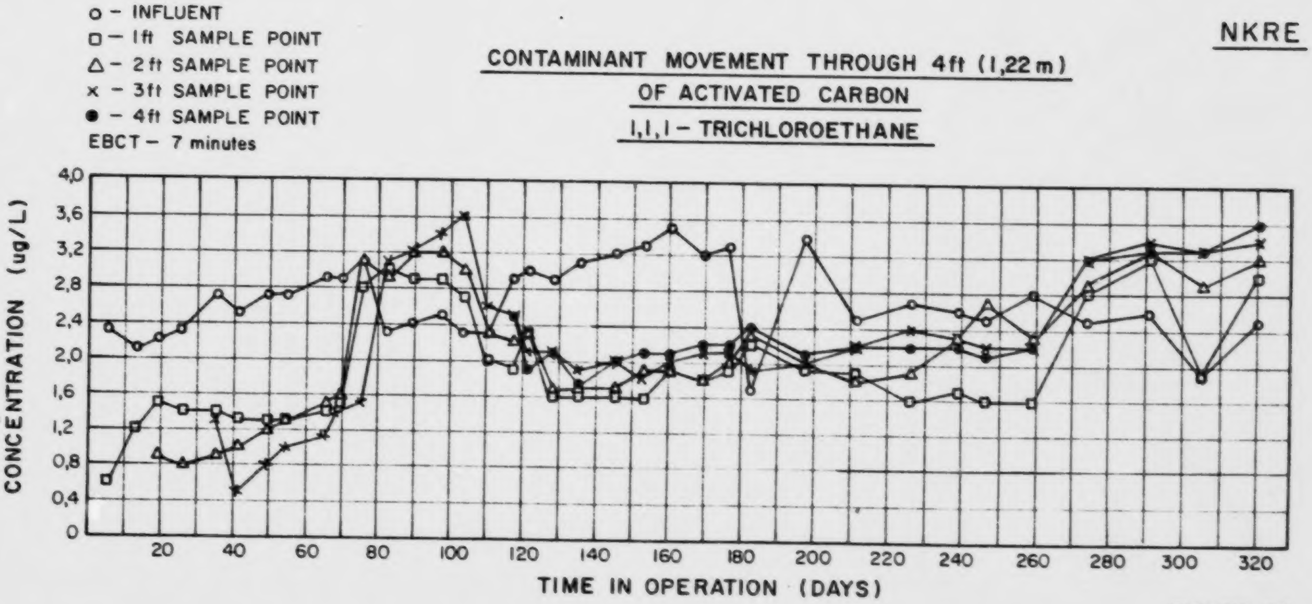


FIGURE 45

TABLE 7
GLEN COVE - PILOT PLANT - PHASE III
GRANULAR ACTIVATED CARBON STUDIES
CONTAMINANT MOVEMENT (WAVE FRONT)
SUMMARY

Concentration	Sample Tap Depth (ft)	Days To Achieved Concentration	Average Days Per Foot	Days Per Ft. Per ug/L of Contamination	Average Days Per Ft. Per ug/L of Contamination
1) cis-1,2-dichloroethylene					
80 ug/L	1	12	12	0.15	0.15
	2	23		0.14	
	3	36		0.16	
	4	Exceeded before sampled			
2) trichloroethylene					
40 ug/L	1	19	34.7	0.48	0.76
	2	66		0.83	
	3	105		0.88	
	4	139		0.87	
80 ug/L	1	32	40	0.4	0.47
	2	80		0.5	
	3	117		0.49	
	4	160		0.50	
120 ug/L	1	40	42.7	0.33	0.35
	2	84		0.35	
	3	127		0.35	
	4	171		0.36	
3) tetrachloroethylene					
5 ug/L	1	65	75.5	13.0	15.6
	2	170		17.0	
	3	263		17.5	
	4	201		15.1	
10 ug/L	1	85	82	8.5	9.3
	2	220		11.0	
	3	285		9.5	
	4	328*		8.2	

(Cont'd)

TABLE 7

GLEN COVE - PILOT PLANT - PHASE III

GRANULAR ACTIVATED CARBON STUDIES

CONTAMINANT MOVEMENT (WAVE FRONT)

SUMMARY

(Cont'd)

Concentration	Sample Tap Depth (ft)	Days To Achieved Concentration	Average Days Per Foot	Days Per Ft. Per ug/L of Contamination	Average Days Per Ft. Per ug/L of Contamination
4) **1,1,1,-trichloroethane**					
1.0 ug/L	1	10	12	10.0	16.2
	2	41		20.5	
	3	54		18.0	
	4	Exceeded before sampled		--	

* Projected from graph

SECTION 6

ESTIMATED FULL SCALE INSTALLATIONS - COSTS

A. ADAPTABILITY OF SYSTEMS

1. Diffused Aeration System

As indicated in the reports for the previous two phases this system can be designed and installed for a full-scale operation if the desired contaminant removal is not less than that achievable at the air to water ratios used in the three phases. It must be restated that the diffused aeration system should be capable of producing a water quality which would meet present New York State guidelines and one that would be acceptable in most areas.

2. Induced Air Packed Spray Aeration System

This column produced a better water quality than the diffused aeration system. This system, however, was not completely tested and optimum design parameters such as hydraulic loading and the proper air to water ratio should be determined before a full-scale plant is installed. The Munters Corporation, manufacturer of the packing utilized in this column testing, has a computer program to determine the sizing of the system which may be sufficient for a full-scale operation. A sample of their results of this program is presented in Appendix G.

3. Air-lift Pumping

This approach does not appear to meet any acceptable guidelines for the contaminants tested during this study. It should be noted that the air-lift pump, used for testing at the Glen Cove site, was not operating in an optimum mode and should be further evaluated before a decision as to the possibility of full-scale installation is determined.

4. Packed Column Air Stripper

The packed column air stripping column tested by U.S. EPA at the Glen Cove site produced a high quality of effluent, the best of the aeration systems tested, and approaching the removal by virgin resins. The necessary design parameters are available to design a full-scale operation. This system should produce a water quality acceptable under most criteria for drinking water supplies.

5. Resin Systems

As indicated in the reports for the other phases, the resin system achieved a better water quality than any of the aeration systems evaluated when considering virgin or new regenerated resins. The results of this phase indicate that the flow application rate (hydraulic loading) should be determined based on the desired concentration in the water supply and the economics of the system to achieve the various hydraulic loading. The regeneration with steam was not further developed during this phase. The resin systems can be designed and a full-scale operation installed. Under present development the steam condensate produced would be hauled to an approved chemical disposal site.

6. Combined Aeration-Resin System

During this phase it was shown that the length of operating cycles of a resin system can be extended by using aeration to pretreat the water prior to adsorption on the resin. This was evident at all flow rates compared. The data developed during Phase III indicates that the hydraulic loading rate for the resin even after pre-aeration should be determined evaluating the economics based on a selected concentration in the water supply.

B. ESTIMATED COSTS FOR FULL-SCALE INSTALLATIONS

As in the Phase I and II reports flows of 1, 2 and 5 mgd (3785, 7575 and 18,925 m3/day) were utilized to obtain a range of costs for a full-scale installation. These flows were utilized in the costing of the diffused aeration system, induced air packed column spray aeration system, air-lift pump system, packed column air-stripping system, and resin system. All costs in the report were estimated by NKRE using the most recently available costing information in February 1983. All the estimated costs include required buildings for equipment and electricity but not laboratory, offices or facilities for workmen.

1. Diffused Aeration System

Utilizing the flows previously indicated and based on a 20:1 air to water ratio, the units necessary for the aeration system, shown schematically on Figure 46, were sized and their costs estimated. The estimated costs include the replacement of a high pressure well pump with a low-lift well pump, storage-aeration tank for 25 minutes detention time, pumps to feed the distribution system after treatment and a control building to house the blowers, distribution pumps, electrical equipment and required instrumentation. The storage-aeration tank should provide sufficient capacity to guarantee a continuous water supply to the consumer in case of well pump failure. This 25-minute designed detnetion time will most likely result in improved effluent quality over that achieved by the 10-minute detention time utilized during the Phase II study. Based on the parameters and the system as indicated on Figure 46, the estimated capital costs for the flows indicated range from $270,000 to $563,000. The estimated annual operating costs, including amortization, maintenance, operations and electricity at a cost of $0.09 per kWh, range from $136,000 to $363,500, or between $0.20 and $0.37 per 1000 gallons (3,785 liters) of treated water. These costs are relatively high, mainly due to the cost of electricity. A summary of the estimated costs are presented on Table 8 and on Figures 47, 48 and 49.

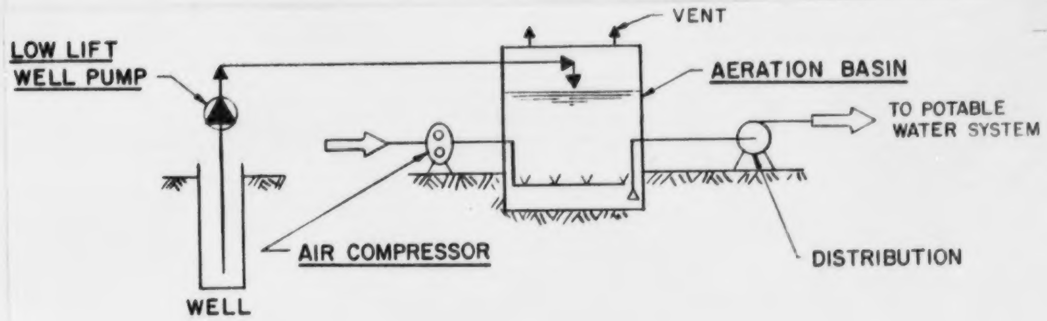
2. Air-lift Pumping

Utilizing the flows previously indicated and based on a 10:1 air to water ratio in the well the cost estimates for an air-lift pumping operation were preapred. It must be noted that an air-lift pumping system is different than other treatment systems in that a system must be installed for each individual well. Certain items, such as a storage basin or tank, and distribution pumps, can be common for wells which are in the same well field but the actual air-lift pump system for each well would operate individually. The estimated cost includes the replacement of a high pressure well pump with a low-lift pump, storage tank for 25 minutes detention time, pumps to feed the distribution system, control building, compressors, and all required electrical equipment and instrumentation. Based on these parameters the estimated capital costs for the flows indicated range from $274,000 to $730,000. The estimated annual operating costs, including amortization, maintenance, operation and electricity at $0.09 per kWh, range from $152,000 to $438,500 or between $0.24 and $0.42 per 1000 gallons (3,785 liters) of treated water. A summary of the costs is presented on Table 9 and on Figures 50, 51 and 52.

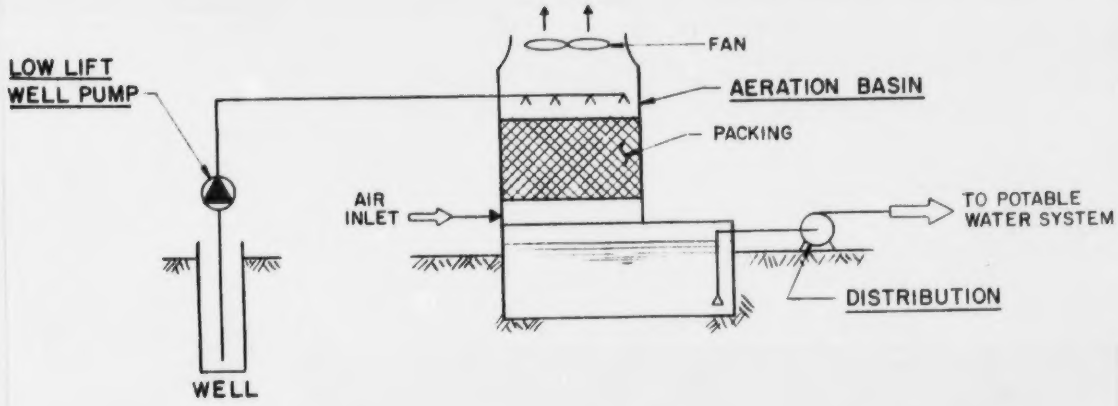
3. Induced Air Packed Column Spray Aeration System

During the testing, the parameters which produced the best water quality were an application rate of 4.5 gpm/ft2 (6.13 m/hr) and an air to water ratio at 2000 to 1.

NKRE


VENT
LOW LIFT WELL PUMP
AERATION BASIN
TO POTABLE WATER SYSTEM
AIR COMPRESSOR
DISTRIBUTION
WELL

DIFFUSED AERATION SYSTEM


FAN
LOW LIFT WELL PUMP
AERATION BASIN
PACKING
AIR INLET
TO POTABLE WATER SYSTEM
DISTRIBUTION
WELL

INDUCED AIR SPRAY/ AIR-STRIPPER PACKED COLUMN

FIGURE 46

TABLE 8
COST ESTIMATE - DIFFUSED AERATION SYSTEM
(Based on 1983 Dollars)

	1 MGD (3785 m3/d)	2 MGD (7570 m3/d)	5 MGD (18925 m3/d)
A. CAPITAL COST			
1. Excavation	1,000	1,500	2,500
2. Concrete	44,000	54,500	80,500
3. Low-lift Well Pump	30,000	37,000	53,500
4. Distribution Pump	15,000	16,000	40,500
5. Air Blower	49,000	66,000	149,000
6. Piping, Valves, etc.	22,500	30,000	67,500
7. Superstructure	83,000	83,000	104,000
8. Heating and Ventilating	7,000	7,000	9,500
9. Elec. & Instr.	19,000	25,000	57,000
	270,000	320,000	563,000
B. ANNUAL OPERATING COST			
1. Electricity			
0.03/kWh	20,000	40,000	80,000
0.06/kWh	40,000	80,000	160,000
0.09/kWh	60,000	120,000	240,000
0.12/kWh	80,000	160,000	320,000
0.15/kWh	100,000	200,000	400,000
2. Maintenance (3% of Equipment Cost)	5,000	5,500	11,500
3. Operators	25,000	25,000	25,000
4. Quality Control	12,000	12,000	12,000
5. Amortization			
Construction (@ 8% for 20 yrs; CFR=0.10185)	13,000	14,000	19,000
Mechanical (@ 8% for 10 yrs; CFR=0.14903)	21,000	27,000	56,000
Total Estimated Annual Cost			
0.03/kWh	96,000	123,400	203,500
0.06/kWh	116,000	163,500	283,500
0.09/kWh	136,000	203,500	363,500
0.12/kWh	156,000	243,500	443,500
0.15/kWh	176,000	283,500	523,500
Cost per 1000 gal. Treated			
0.03/kWh	0.263	0.169	0.111
0.06/kWh	0.319	0.224	0.155
0.09/kWh	0.373	0.279	0.199
0.12/kWh	0.427	0.334	0.243
0.15/kWh	0.482	0.388	0.287

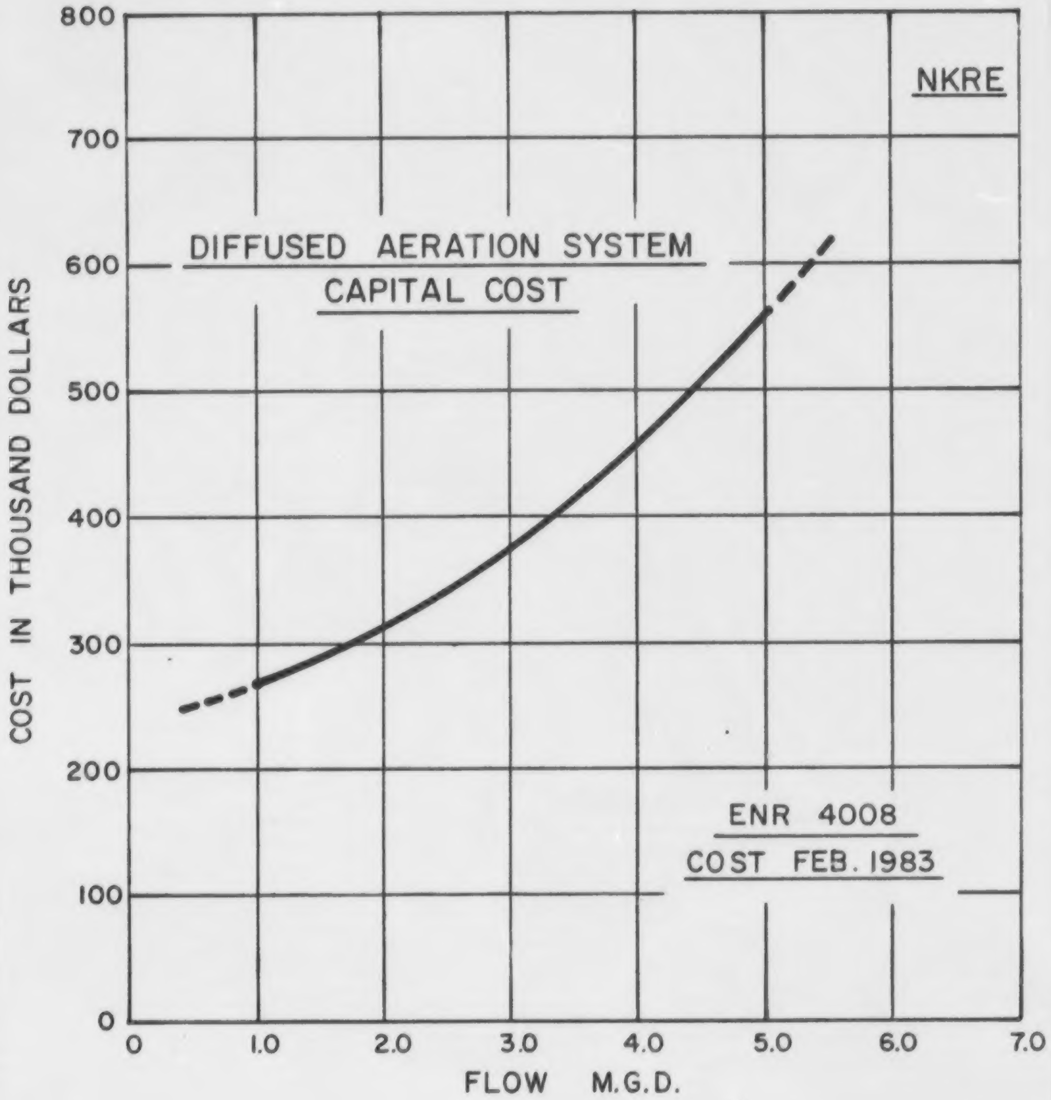

NKRE
DIFFUSED AERATION SYSTEM
CAPITAL COST
ENR 4008
COST FEB. 1983
COST IN THOUSAND DOLLARS
800
700
600
500
400
300
200
100
0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 47

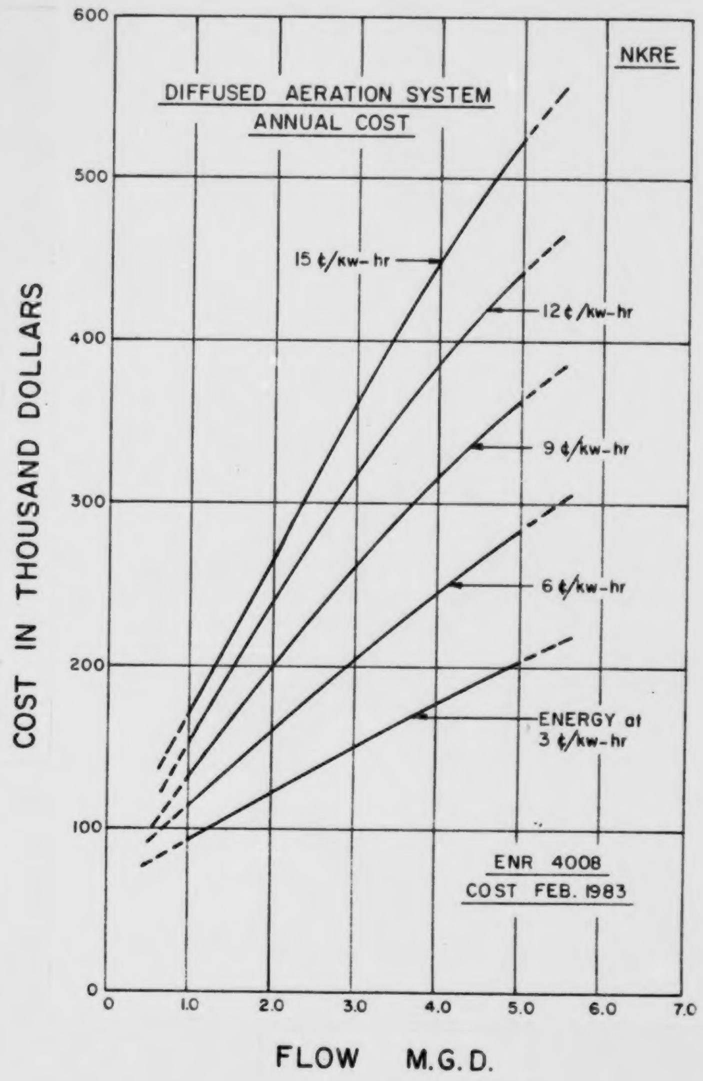

DIFFUSED AERATION SYSTEM
ANNUAL COST
NKRE
15 ¢/kw-hr
12 ¢/kw-hr
9 ¢/kw-hr
6 ¢/kw-hr
ENERGY at 3 ¢/kw-hr
ENR 4008
COST FEB. 1983
COST IN THOUSAND DOLLARS
0
100
200
300
400
500
600
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 48

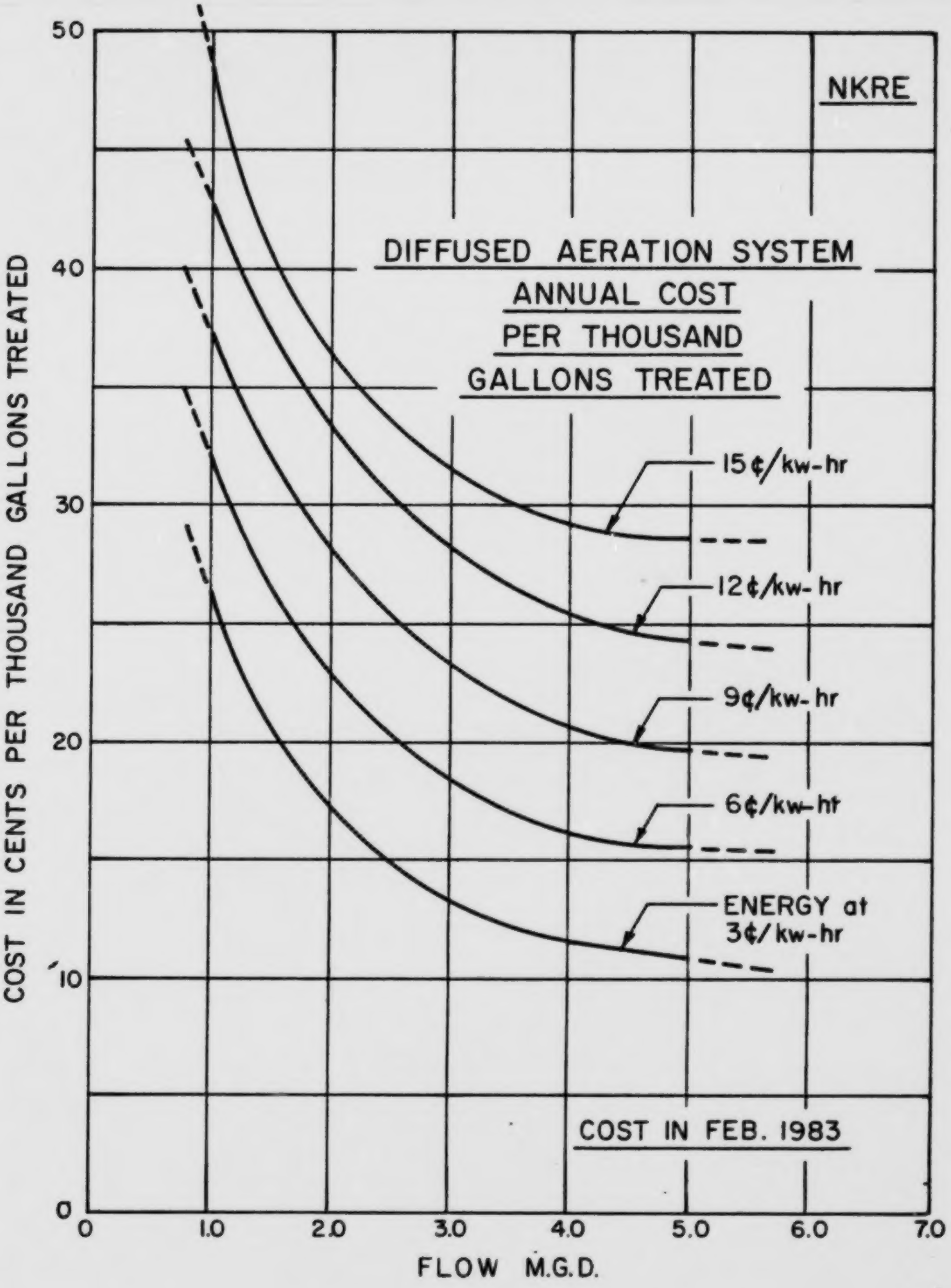

NKRE
DIFFUSED AERATION SYSTEM
ANNUAL COST
PER THOUSAND
GALLONS TREATED
15¢/kw-hr
12¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY at
3¢/kw-hr
COST IN FEB. 1983
COST IN CENTS PER THOUSAND GALLONS TREATED
0
10
20
30
40
50
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 49

TABLE 9
COST ESTIMATE - AIR-LIFT PUMP SYSTEM
(Based on 1983 Dollars)

	1 MGD (3785 m3/d)	2 MGD (7570 m3/d)	5 MGD (18925 m3/d)
A. CAPITAL COST			
1. Excavation	1,500	2,000	3,500
2. Concrete	31,500	49,500	67,500
3. Air-lift Well Pump	16,000	26,000	68,000
4. Distribution Pump	15,000	16,000	46,500
5. Air Compressors	148,000	217,000	400,000
6. Piping, Valves, etc.	10,000	17,000	39,000
7. Control Building	20,000	20,000	20,000
8. Heating and Ventilating	7,000	8,000	12,000
9. Elec. & Instr.	25,000	40,000	80,000
	274,000	395,500	730,500
B. ANNUAL OPERATING COST			
1. Electricity			
0.03/kWh	25,000	50,000	100,000
0.06/kWh	50,000	100,000	200,000
0.09/kWh	75,000	150,000	300,000
0.12/kWh	100,000	200,000	400,000
0.15/kWh	125,000	250,000	500,000
2. Maintenance (3% of Equipment Cost)	5,000	7,000	11,000
3. Operators	25,000	25,000	25,000
4. Quality Control	12,000	12,000	12,000
5. Amortization			
Construction (@ 8% for 20 yrs; CFR=0.10185)	14,000	21,000	40,000
Mechanical (@ 8% for 10 yrs; CFR=0.14903)	21,000	36,500	50,500
Total Estimated Annual Cost			
0.03/kWh	102,000	151,500	238,500
0.06/kWh	127,000	201,500	338,500
0.09/kWh	152,000	251,500	438,500
0.12/kWh	177,000	301,500	538,500
0.15/kWh	202,000	351,500	638,500
Cost per 1000 gal. Treated			
0.03/kWh	0.279	0.207	0.131
0.06/kWh	0.348	0.276	0.185
0.09/kWh	0.416	0.345	0.240
0.12/kWh	0.485	0.413	0.295
0.15/kWh	0.553	0.482	0.350

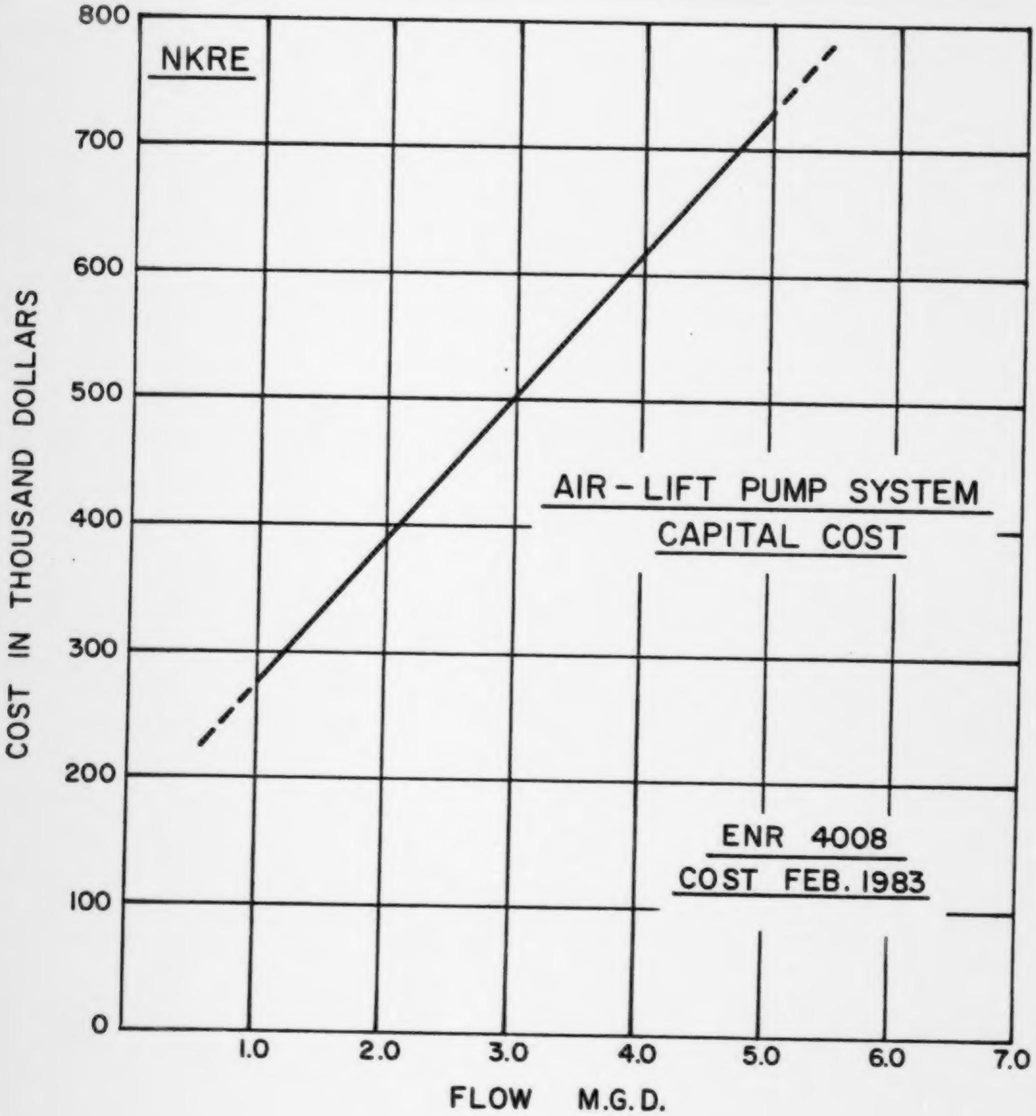

NKRE
AIR-LIFT PUMP SYSTEM CAPITAL COST
ENR 4008 COST FEB. 1983
COST IN THOUSAND DOLLARS
0
100
200
300
400
500
600
700
800
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 50

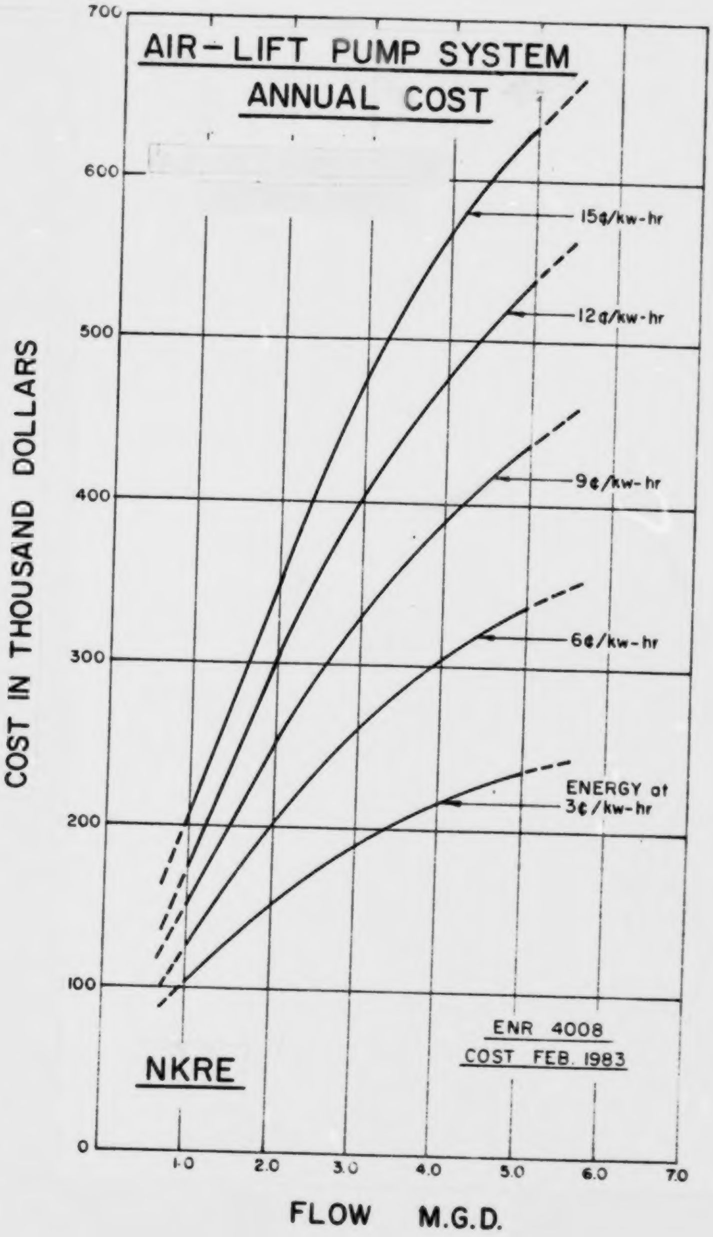

AIR-LIFT PUMP SYSTEM
ANNUAL COST
COST IN THOUSAND DOLLARS
0
100
200
300
400
500
600
700
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.
15¢/kw-hr
12¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY at
3¢/kw-hr
NKRE
ENR 4008
COST FEB. 1983

FIGURE 51

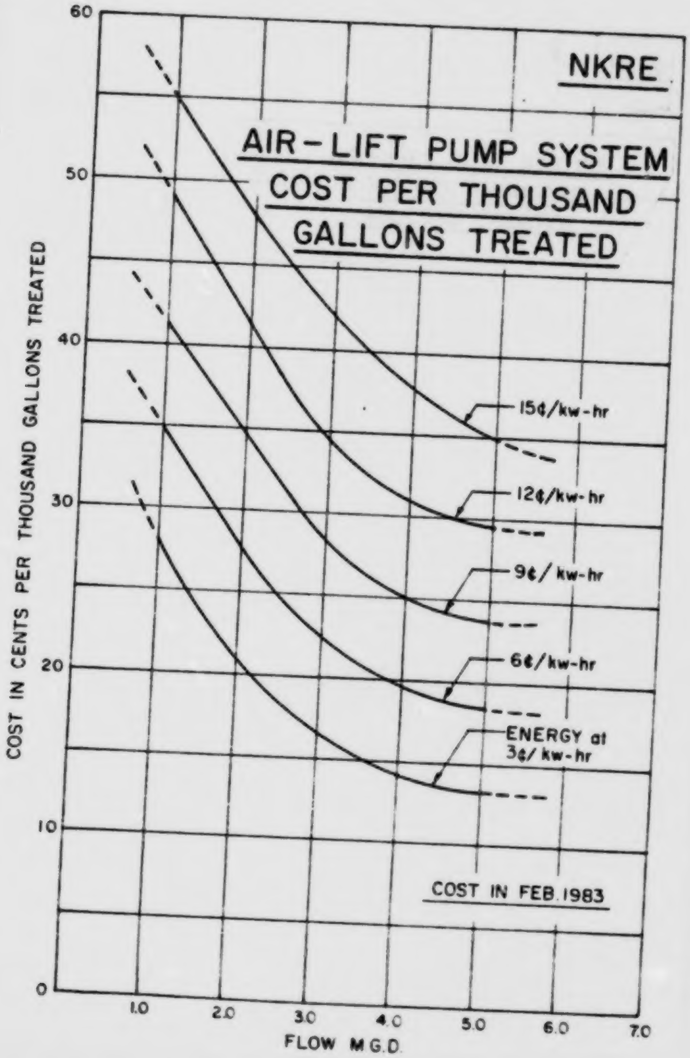

NKRE
AIR-LIFT PUMP SYSTEM COST PER THOUSAND GALLONS TREATED
COST IN CENTS PER THOUSAND GALLONS TREATED
60
50
40
30
20
10
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.
15¢/kw-hr
12¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY at 3¢/kw-hr
COST IN FEB. 1983

FIGURE 52

During the test period it did not appear that the system was operated at optimum conditions due to the physical constraints of the pilot plant installation. The data developed seem to indicate that a much higher application rate and lower air to water ratio are possible. Based on this realization and the review of the data developed by the U.S. EPA for the packed column air-stripping system it was decided to base the air to water ratio on 60 to 1 but retain the application rate of 4.5 gpm/ft2 (6.13 m/hr) for the cost estimate. The cost prepared for this report should be compared with the computer calculated system provided by the packing manufacturer Munters Corporation which is presented in Appendix G. The estimated capital cost presented by the manufacturer includes only the tower, packing and mist eliminator and the estimated annual operating cost includes only the fan and supply pump. The units necessary for the induced air packed column spray aeration system are presented schematically on Figure 46. Utilizing this system, the previously indicated design parameters, the flows indicated and including the replacement of a high pressure well pump with a low-lift well pump, storage basin for 25 minutes detention time, pumps to feed the distribution system, fan assembly to induce ambient air into the system, control building, all necessary electrical equipment and instrumentation and including packing material (based on Munters packing) the estimated capital costs range from $231,000 to $629,500. The estimated annual operating costs for this system including amortization, maintenance, operation and electricity at a cost of $0.09 per kWh range from $82,000 to $188,500 or between $0.10 and $0.23 per 1000 gallons (3,785 liters) of treated water. A summary of the estimated costs is presented on Table 10 and on Figures 53, 54 and 55.

4. Packed Column Air-Stripping System

This system is based on the column tested at the Glen Cove site by U.S. EPA personnel twice during the Phase III operations. The cost estimates were prepared utilizing the test parameters which produced the best effluent quality during the testing, a flow application rate of 25 gpm/ft2 (61.3 m/hr) and an air to water ratio of 60 to 1 and based on the system as indicated schematically on Figure 46. The estimated cost includes required packing (based on 1 inch Glitsch packing used during the testing) and all items included for the induced air-packed column spray aeration system shown schematically on Figure 46. Using the flows previously indicated the system has estimated capital costs ranging from $185,500 to $439,000. The estimated annual operating costs including amortization, maintenance, operations and electricity at a cost of $0.09 and $0.21 per 1000 gallons (3,785 liters) of treated water. A summary of the estimated costs is presented on Table 11 and on Figures 56, 57, and 58.

TABLE 10
COST ESTIMATE - INDUCED AIR PACKED COLUMN SPRAY AERATION SYSTEM
(Based on 1983 Dollars)

	1 MGD (3785 m3/d)	2 MGD (7570 m3/d)	5 MGD (18925 m3/d)
A. CAPITAL COST			
1. Excavation	1,500	2,000	3,500
2. Concrete	49,500	83,500	105,000
3. Low-lift Well Pump	30,000	37,000	52,500
4. Distribution Pump	15,000	16,000	40,500
5. Fan	10,000	16,000	27,000
6. Packing (incl. Supports & Mist eliminator)	65,000	130,000	292,000
7. Piping, Valves, etc.	18,000	21,000	40,000
8. Superstructure	20,000	20,000	25,000
9. H&V	7,000	2,000	9,000
10. Elec. & Instr.	15,000	19,000	35,000
	231,000	346,500	629,500
B. ANNUAL OPERATING COST			
1. Electricity			
0.03/kWh	4,000	8,000	20,000
0.06/kWh	8,000	16,000	40,000
0.09/kWh	12,000	24,000	60,000
0.12/kWh	16,000	32,000	80,000
0.15/kWh	20,000	40,000	100,000
2. Maintenance (3% of Equipment Cost)	3,000	5,000	7,500
3. Operators	25,000	25,000	25,000
4. Quality Control	12,000	12,000	12,000
5. Amortization			
Construction (@ 8% for 20 yrs; CFR=0.10185)	10,000	15,000	21,500
Mechanical (@ 8% for 10 yrs; CFR=0.14903)	20,000	30,000	62,500
Total Estimated Annual Cost			
0.03/kWh	74,000	95,000	148,500
0.06/kWh	78,000	103,000	168,500
0.09/kWh	82,000	111,000	188,500
0.12/kWh	86,000	119,000	208,500
0.15/kWh	90,000	127,000	328,500
Cost per 1000 gal. Treated			
0.03/kWh	0.203	0.130	0.081
0.06/kWh	0.214	0.141	0.092
0.09/kWh	0.225	0.152	0.103
0.12/kWh	0.236	0.163	0.114
0.15/kWh	0.247	0.174	0.125

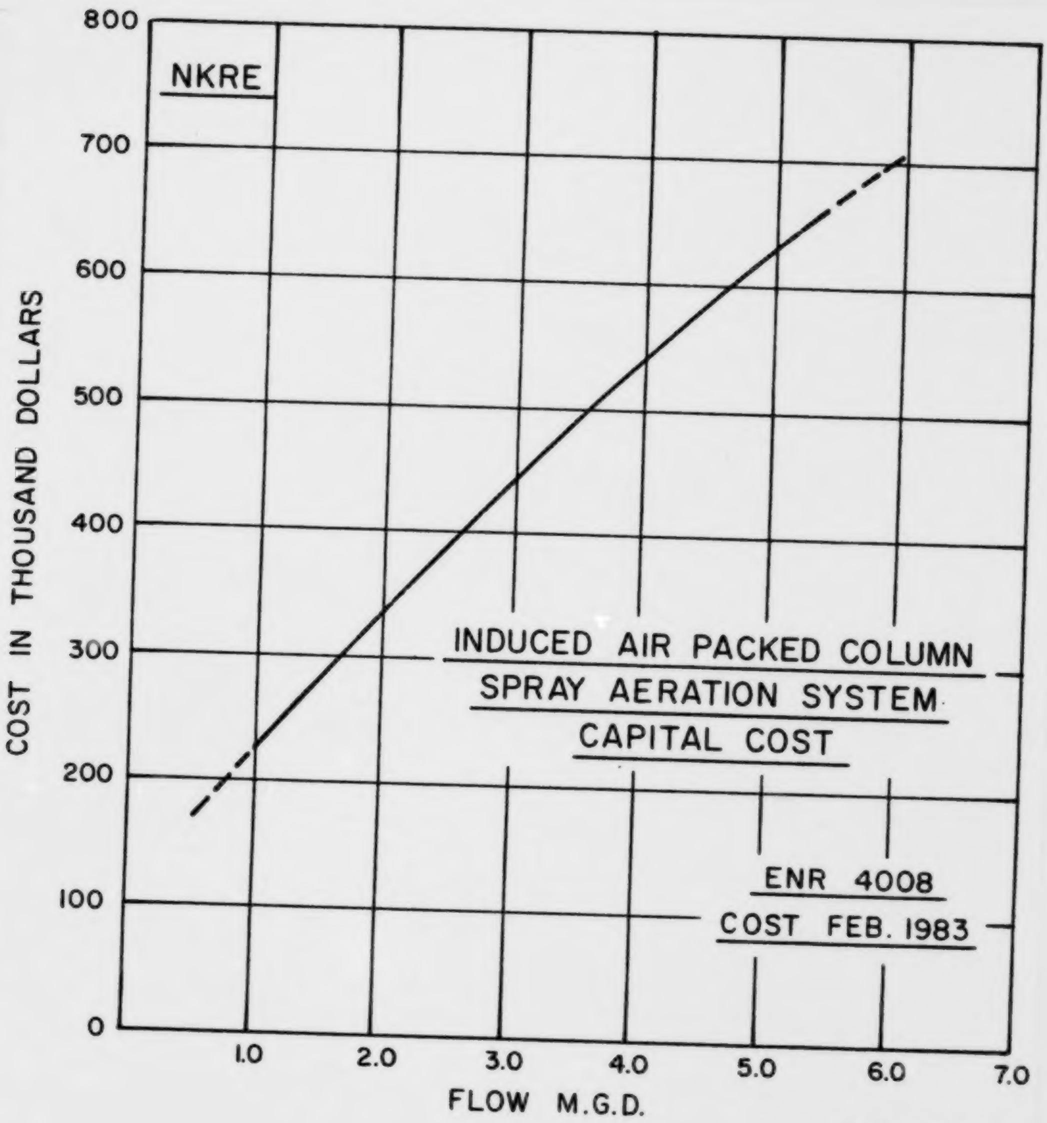
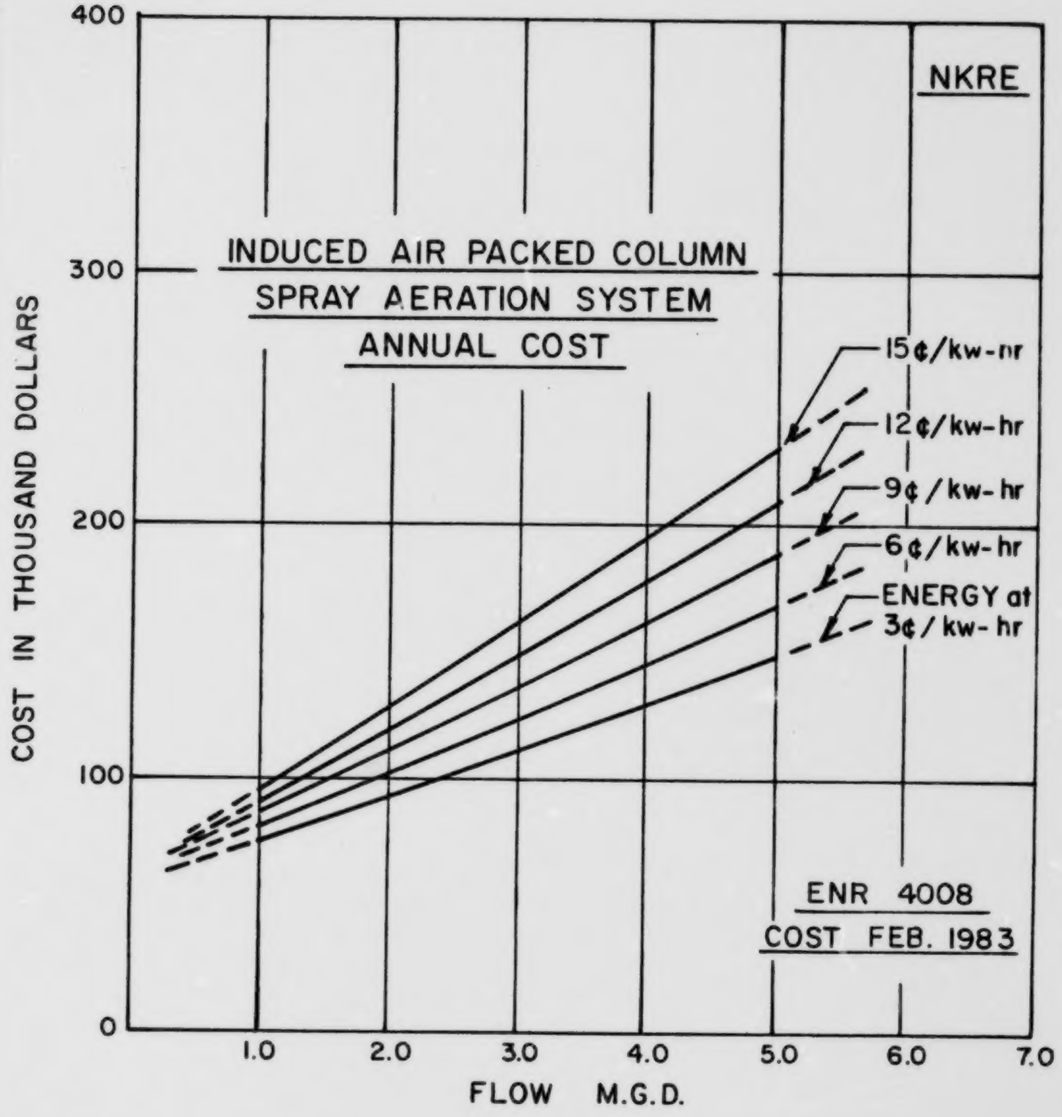

NKRE
COST IN THOUSAND DOLLARS
800
700
600
500
400
300
200
100
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.
INDUCED AIR PACKED COLUMN
SPRAY AERATION SYSTEM
CAPITAL COST
ENR 4008
COST FEB. 1983

FIGURE 53



NKRE
INDUCED AIR PACKED COLUMN
SPRAY AERATION SYSTEM
ANNUAL COST
15¢/kw-hr
12¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY at
3¢/kw-hr
ENR 4008
COST FEB. 1983
COST IN THOUSAND DOLLARS
400
300
200
100
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 54

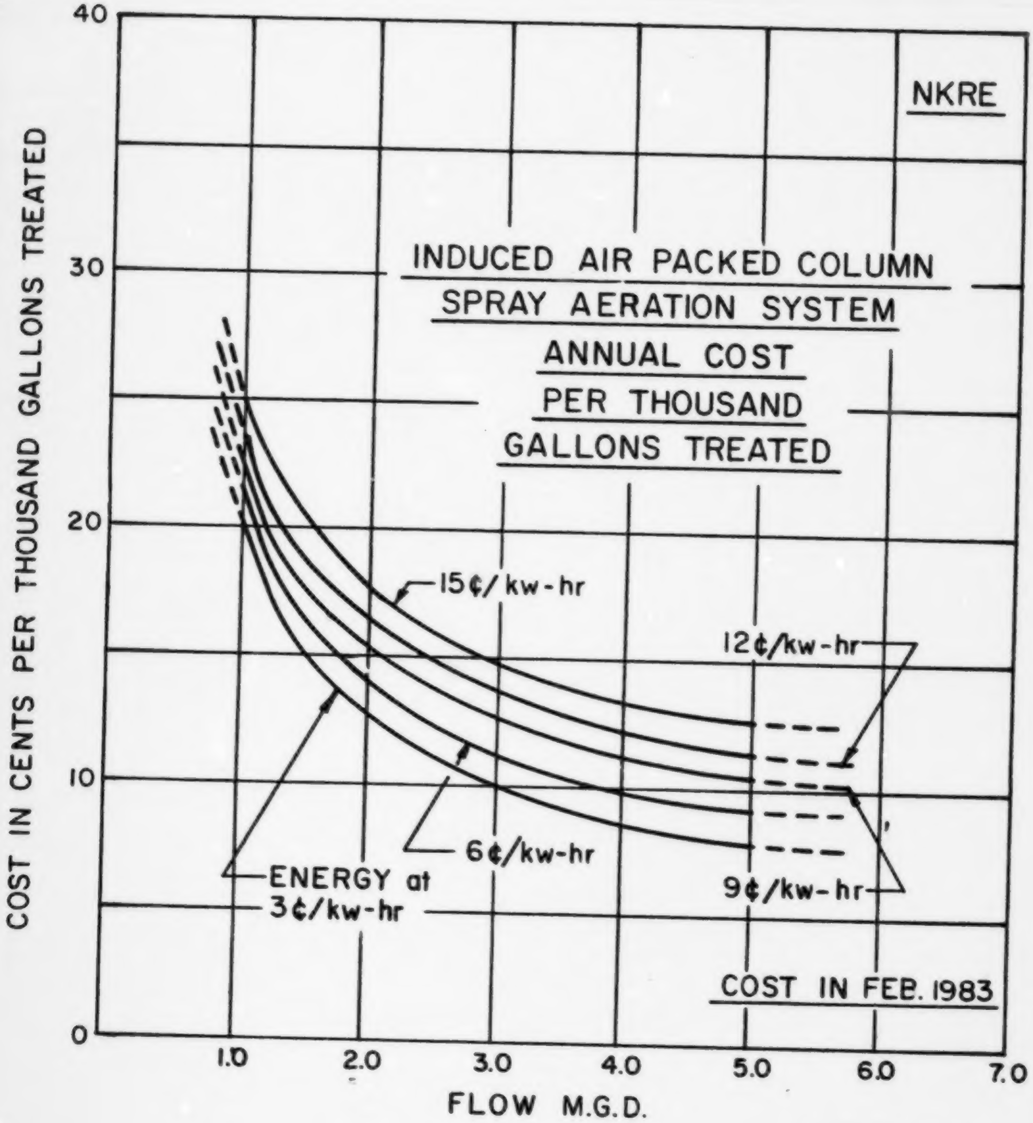

NKRE
INDUCED AIR PACKED COLUMN
SPRAY AERATION SYSTEM
ANNUAL COST
PER THOUSAND
GALLONS TREATED
COST IN CENTS PER THOUSAND GALLONS TREATED
40
30
20
10
0
15¢/kw-hr
12¢/kw-hr
6¢/kw-hr
9¢/kw-hr
ENERGY at
3¢/kw-hr
COST IN FEB. 1983
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 55

TABLE 11
COST ESTIMATE - PACKED COLUMN AIR-STRIPPING SYSTEM
(Based on 1983 Dollars)

	1 MGD (3785 m3/d)	2 MGD (7570 m3/d)	5 MGD (18925 m3/d)
A. CAPITAL COST			
1. Excavation	1,500	2,000	4,000
2. Concrete	44,000	67,500	90,000
3. Low-lift Well Pump	30,000	37,000	52,500
4. Distribution Pump	15,000	16,000	40,500
5. Fan Assembly	10,000	16,000	27,000
6. Packing	24,000	44,000	120,000
7. Piping, Valves, etc.	19,000	21,500	36,000
8. Control Building	20,000	20,000	25,000
9. H&V	7,000	7,000	9,000
10. Elec. & Instr.	15,000	20,000	35,000
	185,500	255,000	439,000
B. ANNUAL OPERATING COST			
1. Electricity			
0.03/kWh	4,000	8,000	20,000
0.06/kWh	8,000	16,000	40,000
0.09/kWh	12,000	24,000	60,000
0.12/kWh	16,000	32,000	80,000
0.15/kWh	20,000	40,000	100,000
2. Maintenance (3% of Equipment Cost)	2,000	3,000	6,000
3. Operators	25,000	25,000	25,000
4. Quality Control	12,000	12,000	12,000
5. Amortization			
Construction (@ 8% for 20 yrs; CFR=0.10185)	9,000	13,000	17,500
Mechanical (@ 8% for 10 yrs; CFR=0.14903)	14,000	19,500	40,000
Total Estimated Annual Cost			
0.03/kWh	66,000	80,500	120,500
0.06/kWh	70,000	88,500	140,500
0.09/kWh	74,000	96,500	160,500
0.12/kWh	78,000	104,500	180,500
0.15/kWh	82,000	112,500	200,500
Cost per 1000 gal. Treated			
0.03/kWh	0.181	0.110	0.066
0.06/kWh	0.192	0.121	0.076
0.09/kWh	0.203	0.132	0.088
0.12/kWh	0.214	0.143	0.099
0.15/kWh	0.225	0.154	0.109

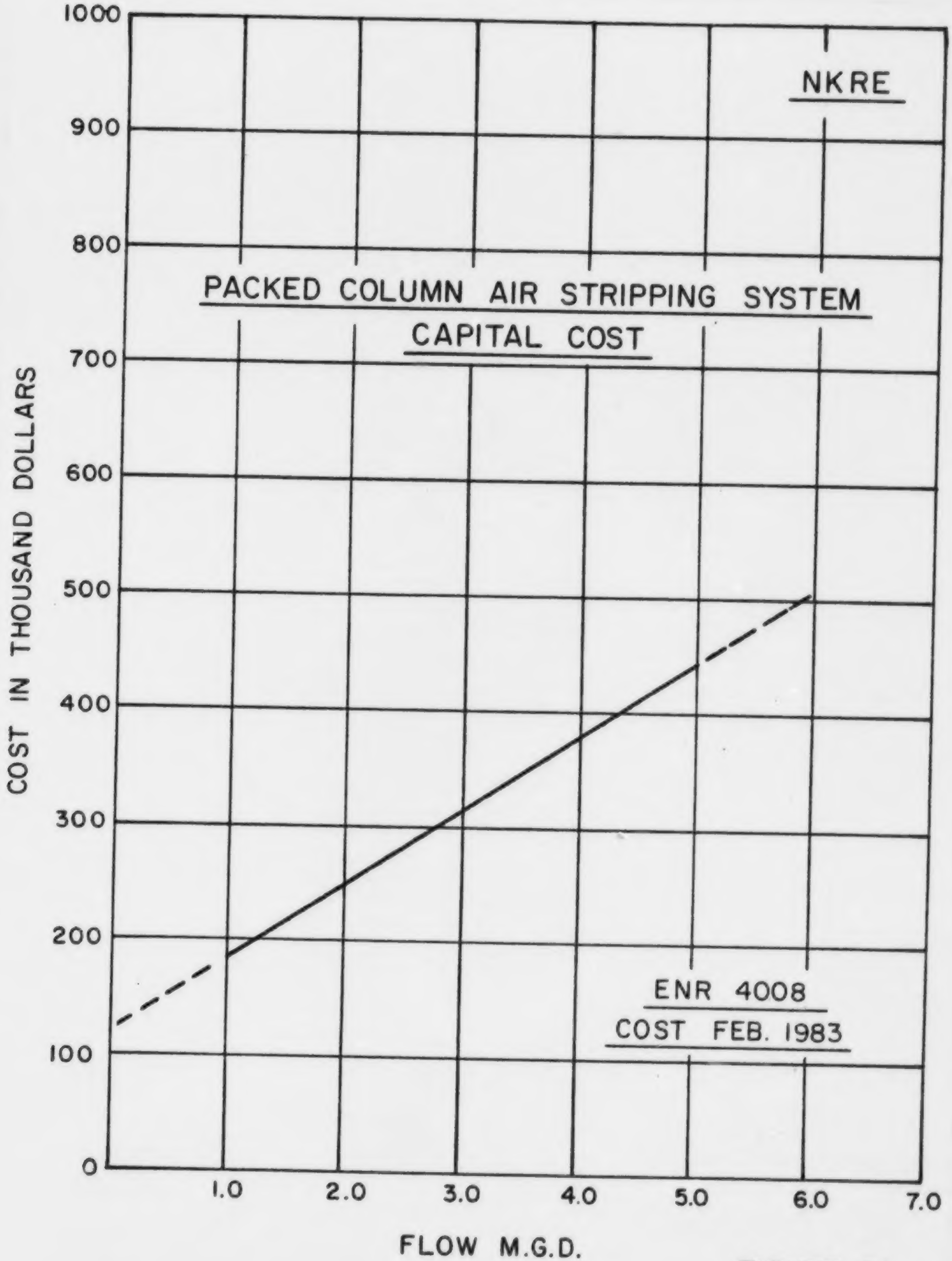

NKRE
PACKED COLUMN AIR STRIPPING SYSTEM
CAPITAL COST
ENR 4008
COST FEB. 1983
COST IN THOUSAND DOLLARS
1000
900
800
700
600
500
400
300
200
100
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 56

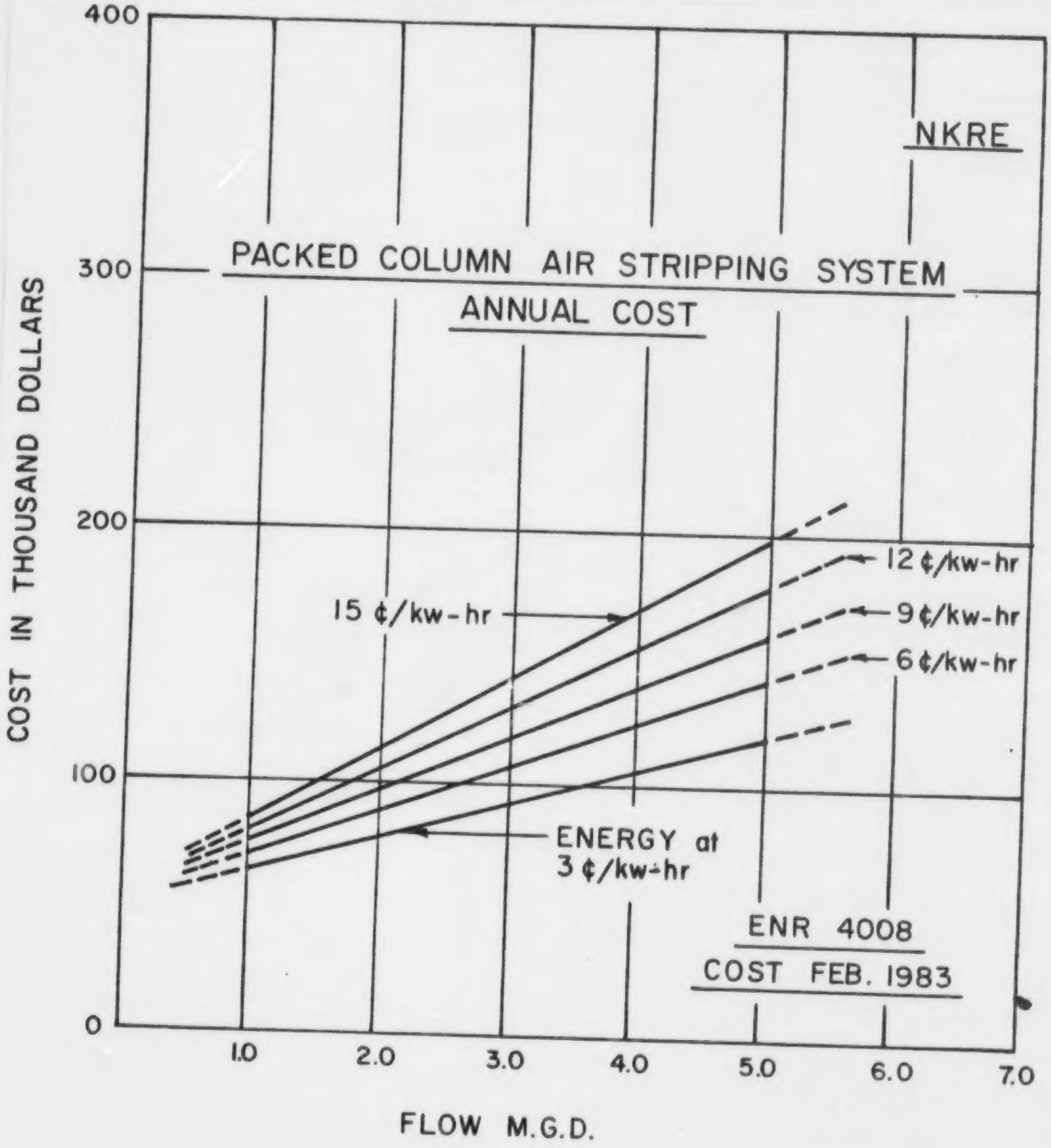

NKRE
PACKED COLUMN AIR STRIPPING SYSTEM
ANNUAL COST
COST IN THOUSAND DOLLARS
400
300
200
100
0
15 ¢/kw-hr
12 ¢/kw-hr
9 ¢/kw-hr
6 ¢/kw-hr
ENERGY at
3 ¢/kw-hr
ENR 4008
COST FEB. 1983
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 57

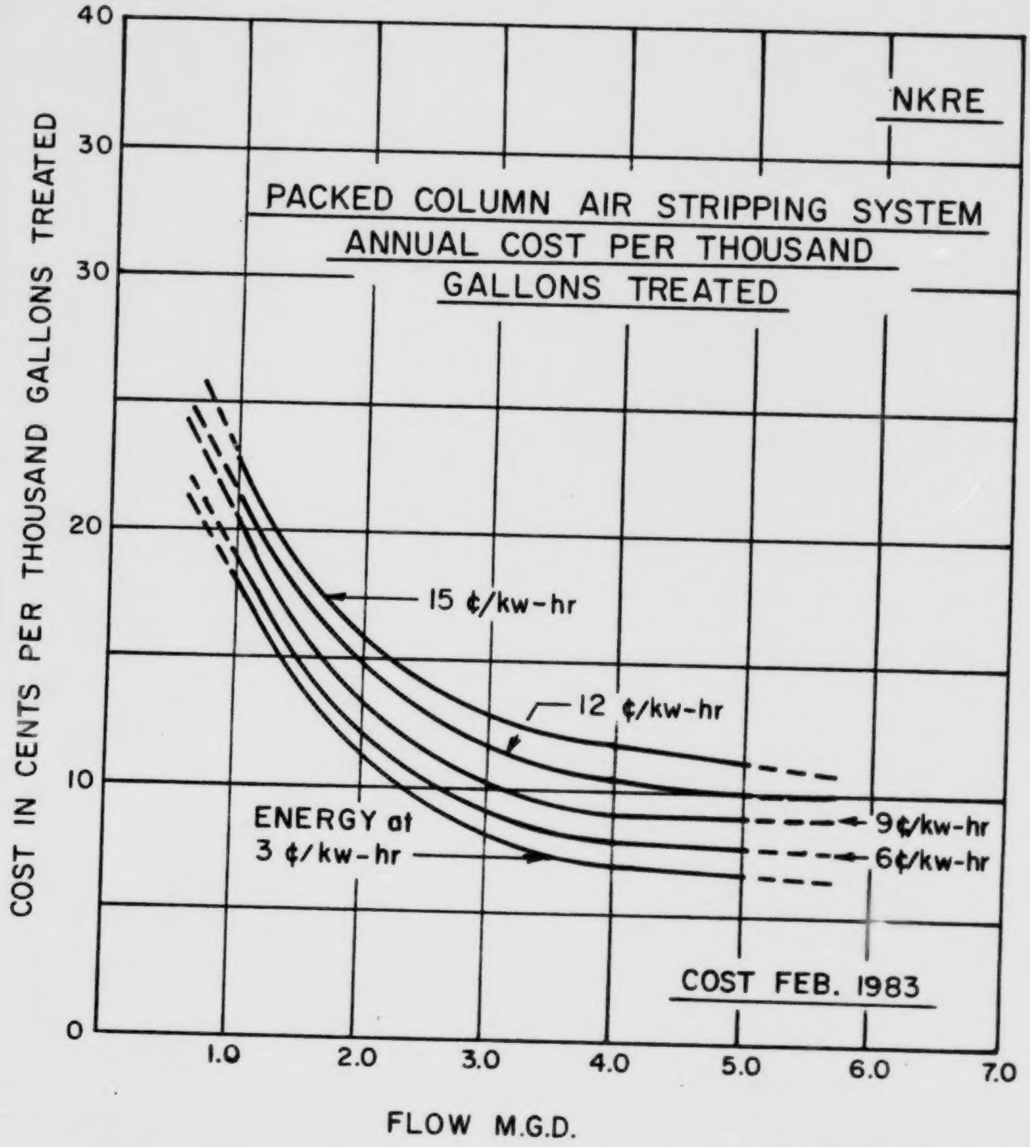

NKRE
PACKED COLUMN AIR STRIPPING SYSTEM
ANNUAL COST PER THOUSAND
GALLONS TREATED
15 ¢/kw-hr
12 ¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY at
3 ¢/kw-hr
COST FEB. 1983
COST IN CENTS PER THOUSAND GALLONS TREATED
40
30
30
20
10
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 58

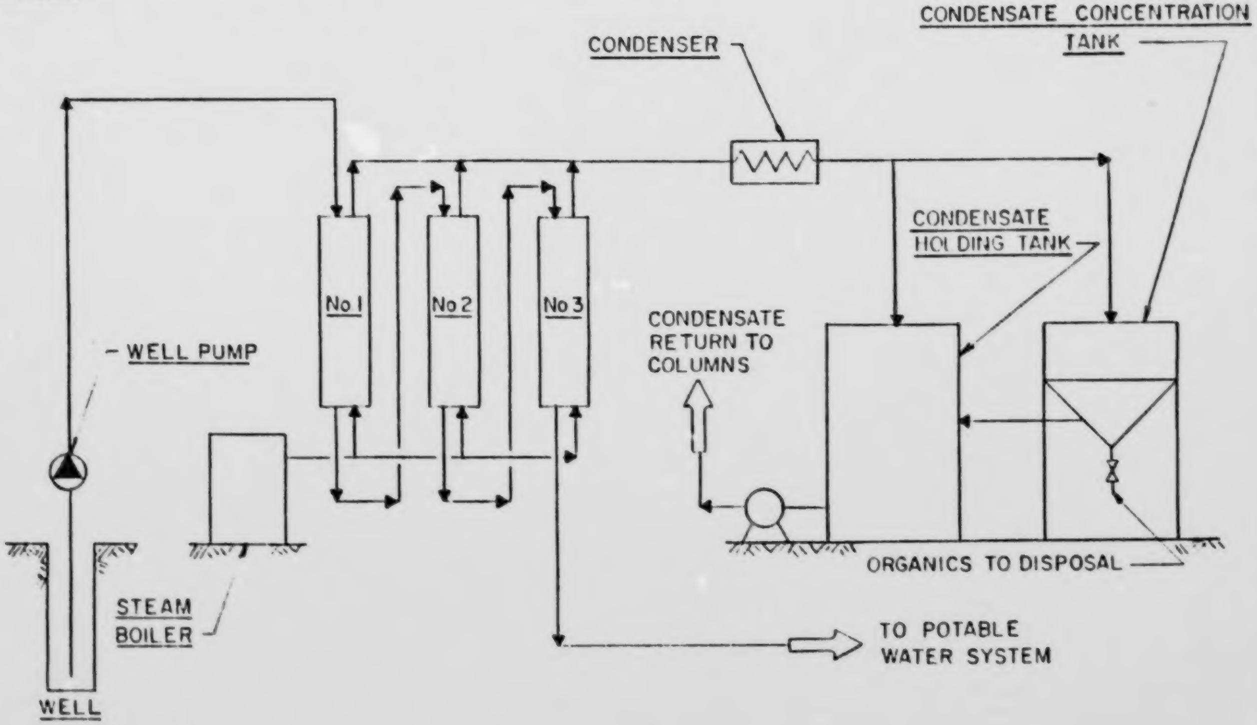
5. Resin System

As in Phase II the estimated costs for Phase III were developed by NKRE utilizing the data obtained during all phases of the program. This estimated cost includes all units shown schematically on Figure 59 necessary to treat the water by resin adsorption, to steam regenerate the resin, to collect and treat the steam condensate and a building to house the entire system. The estimated capital cost, based on an application rate of 4 gpm/ft3 (0.42 lpm/m3) of adsorbent, for the flows indicated range from $432,000 to $1,446,000. The application rate of 4 gpm/ft3 (0.42 Lpm/m3) was selected because it is the rate recommended by the resin manufacturer and the other application rates tested did not provide sufficient reason to change the hydraulic loading. The resin system has an estimated annual operating cost, including amortization, maintenance, operation, fuel for steam production, electricity at $0.09 per kWh, and other requirements such as solvent for hydration, ranging from $0.18 to $0.32 per 1000 gallons (3785 liters) treated. These cost estimates do not include any well or distribution pumps since it was assumed that any existing high pressure well pump would be sufficient to overcome the headloss through the resin and feed the distribution system. The operating cost includes regeneration of each column three (3) times per year. A summary of these estimated costs is presented on Table 12 and on Figures 60, 61 and 62.

6. Combined Aeration Resin Systems

As previously indicated, any of the aeration systems tested during this program could be combined with resin adsorption to produce a high quality water and extend the operating cycles. Since the same conditions apply for the adsorption sector of the combined system as do for the plain resin system, the application rate remains 4 gpm/ft3 (0.42 Lpm/m3) for costing purposes, even after aeration, the savings for the resin system would only be in the operating cost since the system would not have to be regenerated as frequently. This saving would amount to about two percent of the operating cost and would not compensate for the high overall cost of the combined system. Depending on the flow to be treated and the aeration system utilized the capital cost will range from $617,000 to $2,176,500 and the operating cost can vary from $0.26 to $0.73 per 1000 gallons treated. This cost is extremely high and the system should only be considered if extremely high water qualities must be produced.

NKRE


CONDENSER
CONDENSATE CONCENTRATION TANK
No 1
No 2
No 3
CONDENSATE HOLDING TANK
CONDENSATE RETURN TO COLUMNS
WELL PUMP
STEAM BOILER
WELL
ORGANICS TO DISPOSAL
TO POTABLE WATER SYSTEM

RESIN SYSTEM

FIGURE 59

TABLE 12
COST ESTIMATE - RESIN SYSTEM
(Based on 1983 Dollars)

	1 MGD (3785 m3/d)	2 MGD (7570 m3/d)	5 MGD (18925 m3/d)
A. CAPITAL COST			
1. Excavation	500	1,000	1,500
2. Concrete	26,000	33,500	46,500
3. Vessels (insulated)	26,000	52,000	130,500
4. Well Pump	Not incl.	Not incl.	Not incl.
5. Resin (incl. installation & initial solvent for hydrating resin)	146,000	295,000	698,500
6. Distribution Pump	Not incl.	Not incl.	Not incl.
7. Steam Generator	15,500	15,500	15,500
8. Condenser	1,500	1,500	1,500
9. Condensate Holding Tank	28,500	28,500	28,500
10. Condensate Concentration Tank	16,500	16,500	16,500
11. Condensate Transfer Pump	5,000	5,000	5,000
12. Oil Storage Tank (1000 gal.)	2,500	2,500	2,500
13. Piping, Valves, etc.	62,000	135,000	334,000
14. H&V	7,000	9,000	10,500
15. Superstructure	89,000	104,000	141,000
16. Elec. & Instrumentation	6,000	7,000	9,000
	432,000	706,000	1,446,000
B. ANNUAL OPERATING COST			
1. Adsorbent Makeup ($7/lb.) (Estimated life - 8 yrs)	17,000	34,500	86,000
2. Solvent	1,000	1,500	3,500
3. Electricity			
0.03/kWh	500	1,000	2,500
0.06/kWh	1,000	2,000	5,000
0.09/kWh	1,500	3,000	7,500
0.12/kWh	2,000	4,000	10,000
0.15/kWh	2,500	5,000	12,500
4. Fuel (No. 2 oil) (For Steam Generator)	2,500	5,000	12,000
5. Disposal of Organics	400	800	2,000
6. Maintenance (3% of Equipment Cost)	4,500	6,000	12,500
7. Operators	25,000	25,000	25,000
8. Quality Control	12,000	12,000	12,000
9. Amortization			
Construction (8% for 20 yrs; CFR=0.10185)	26,500	43,000	88,000
Mechanical (8% for 10 yrs; CFR=0.14903)	26,000	42,000	87,000

(Cont'd)

TABLE 12
COST ESTIMATE - RESIN SYSTEM
(Based on 1983 Dollars)
(Continued)

	1 MGD (3785 m3/d)	2 MGD (7570 m3/d)	5 MGD (18925 m3/d)
Total Annual Cost			
0.03/kWh	115,400	170,800	330,500
0.06/kWh	115,900	171,800	333,000
0.09/kWh	116,400	172,800	335,500
0.12/kWh	116,900	173,800	338,000
0.15/kWh	117,400	174,800	340,500
Cost per 1000 gal Treated			
0.03/kWh	0.316	0.234	0.181
0.06/kWh	0.317	0.235	0.182
0.09/kWh	0.319	0.237	0.184
0.12/kWh	0.320	0.238	0.185
0.15/kWh	0.322	0.239	0.187

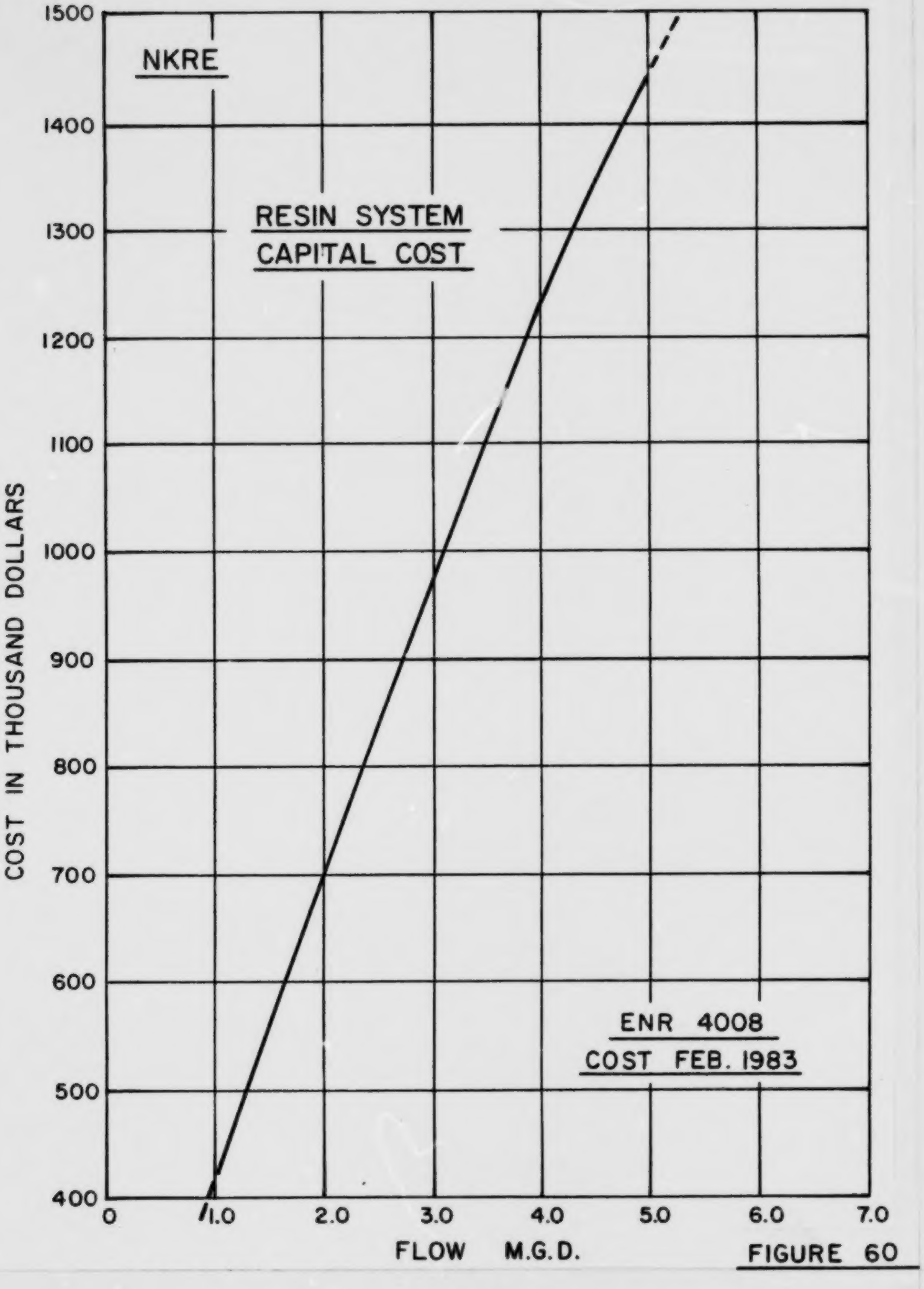

NKRE
RESIN SYSTEM
CAPITAL COST
ENR 4008
COST FEB. 1983
COST IN THOUSAND DOLLARS
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 60

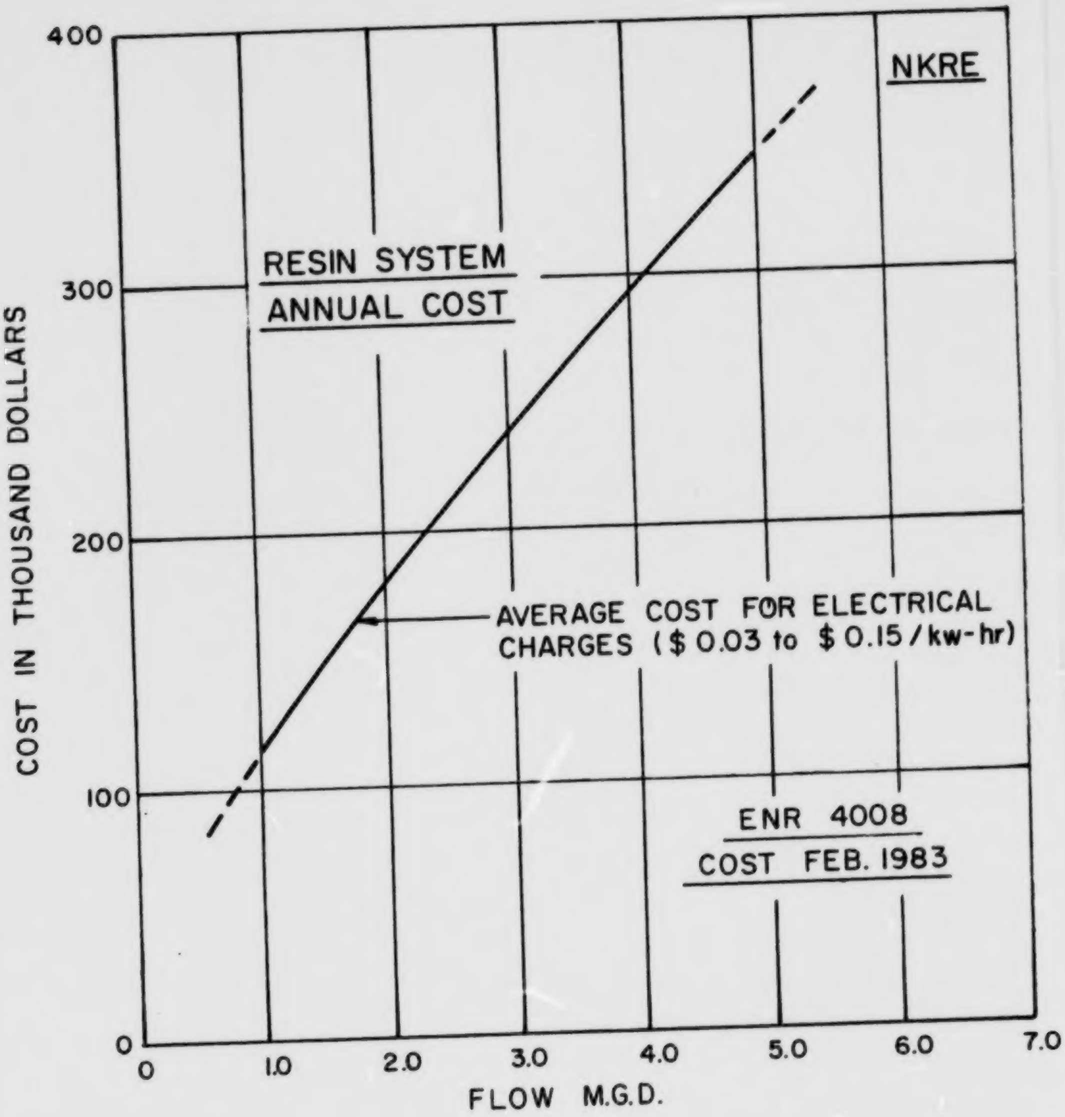

NKRE
RESIN SYSTEM
ANNUAL COST
AVERAGE COST FOR ELECTRICAL CHARGES ($ 0.03 to $ 0.15 / kw-hr)
ENR 4008
COST FEB. 1983
COST IN THOUSAND DOLLARS
400
300
200
100
0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 61

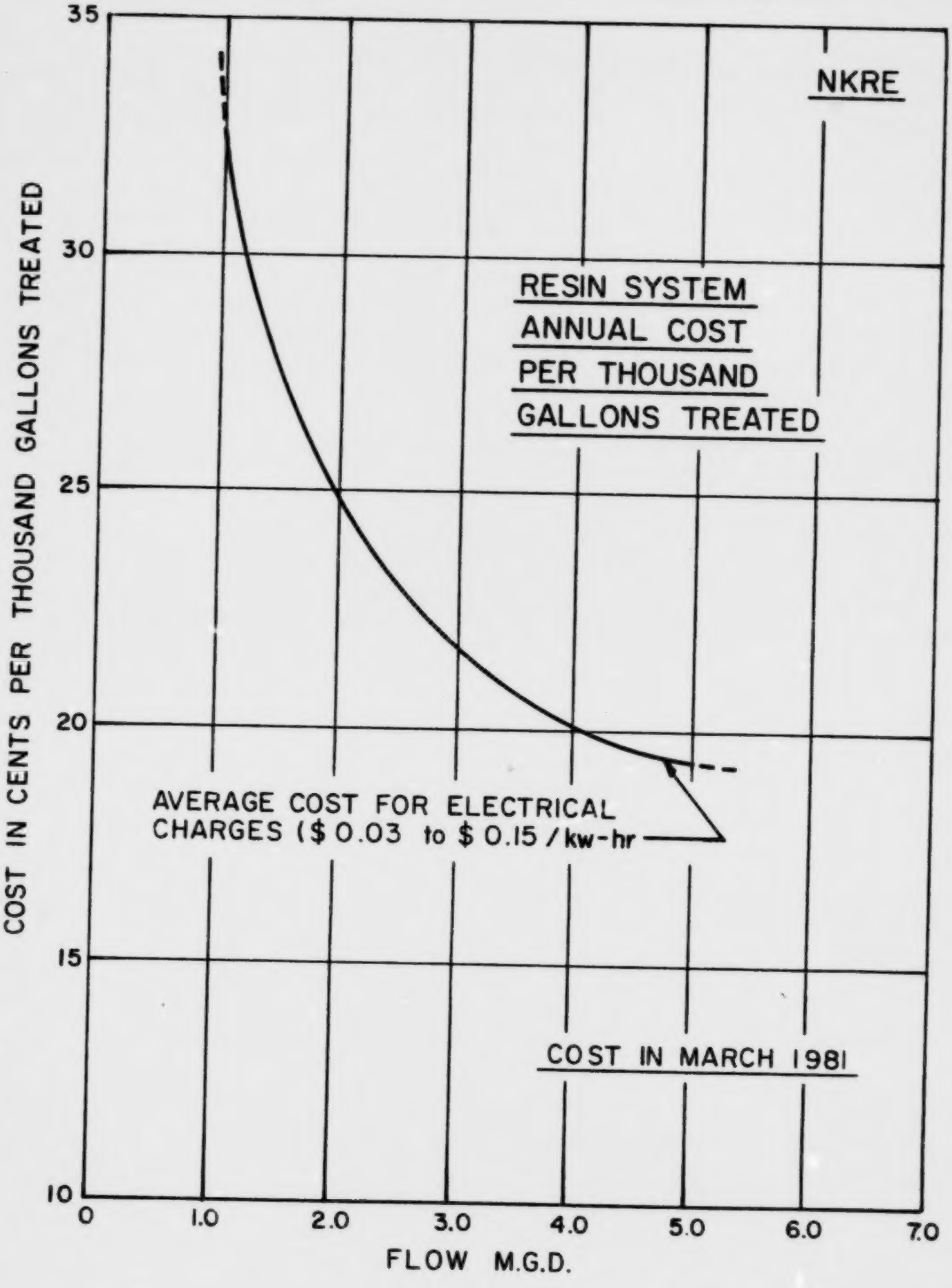

NKRE
RESIN SYSTEM ANNUAL COST PER THOUSAND GALLONS TREATED
AVERAGE COST FOR ELECTRICAL CHARGES ($ 0.03 to $ 0.15 / kw-hr
COST IN MARCH 1981
COST IN CENTS PER THOUSAND GALLONS TREATED
35
30
25
20
15
10
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 62

7. Summary of Estimated Costs

The capital costs for the five treatment methods tested during Phase III, diffused aeration, air-lift pumping, induced air packed column spray aeration, packed column air-stripping and resin adsorption are compared on Figure 63. The data indicate that the resin system has a much higher capital cost than any aeration testing. The lowest capital cost is for the packed column air-stripping system closely followed by the induced air packed column spray aeration system. The diffused aeration system has the third lowest capital cost followed by the air-lift pumping system. A comparison of the annual operating cost per 1000 gallons (3,785 liters) of treated water considering an electrical cost at $0.09/kWh is presented on Figure 64. This figure shows that the air-lift pumping system has the highest operating cost and again the packed column air-stripping system the lowest. The next least operating cost is for the induced air packed column spray aeration system followed by the resin system and the diffused aeration system had the fourth highest operating cost. The higher operating costs for the air-lift pumping and diffused aeration systems are due to the electrical power required to drive the compressors producing the air. These curves indicate the advantage of the use of columns using induced ambient air which require low horsepower to provide the air.

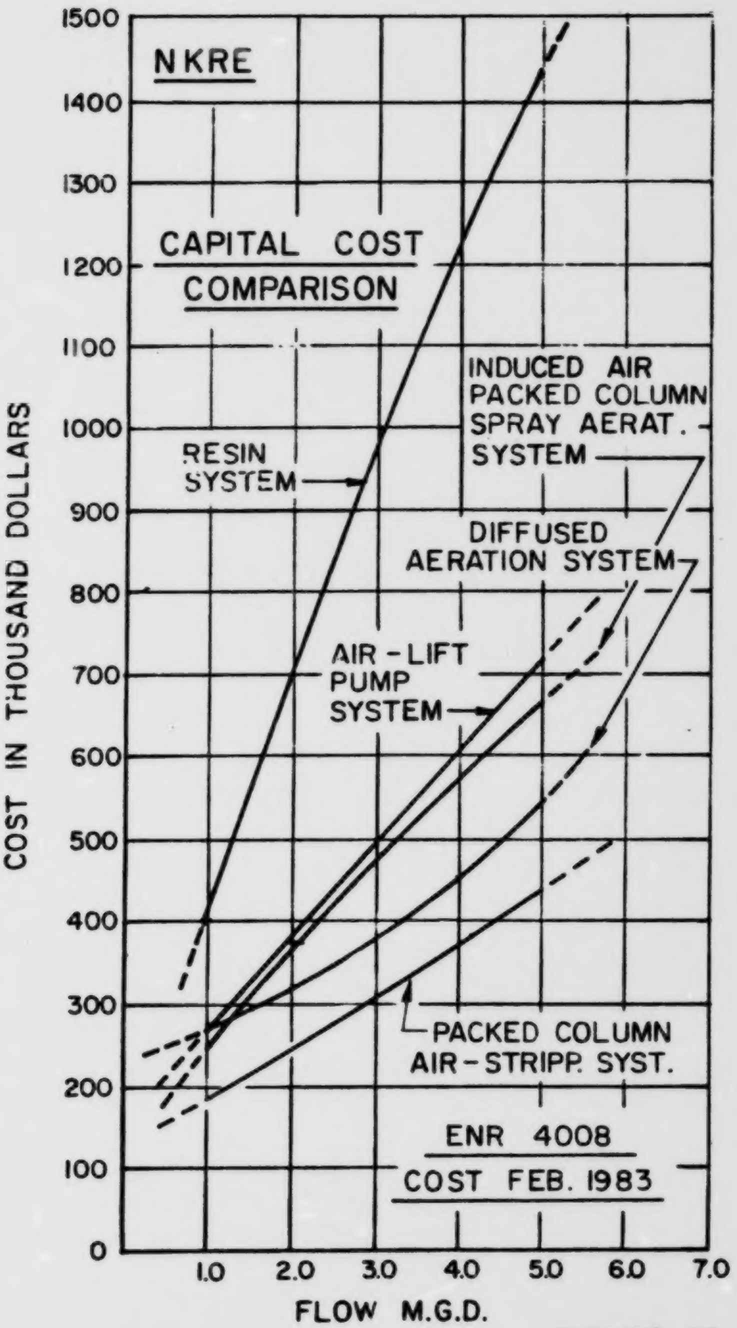

NKRE
CAPITAL COST
COMPARISON
RESIN SYSTEM
INDUCED AIR PACKED COLUMN SPRAY AERAT. SYSTEM
DIFFUSED AERATION SYSTEM
AIR-LIFT PUMP SYSTEM
PACKED COLUMN AIR-STRIPP. SYST.
ENR 4008
COST FEB. 1983
COST IN THOUSAND DOLLARS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 63

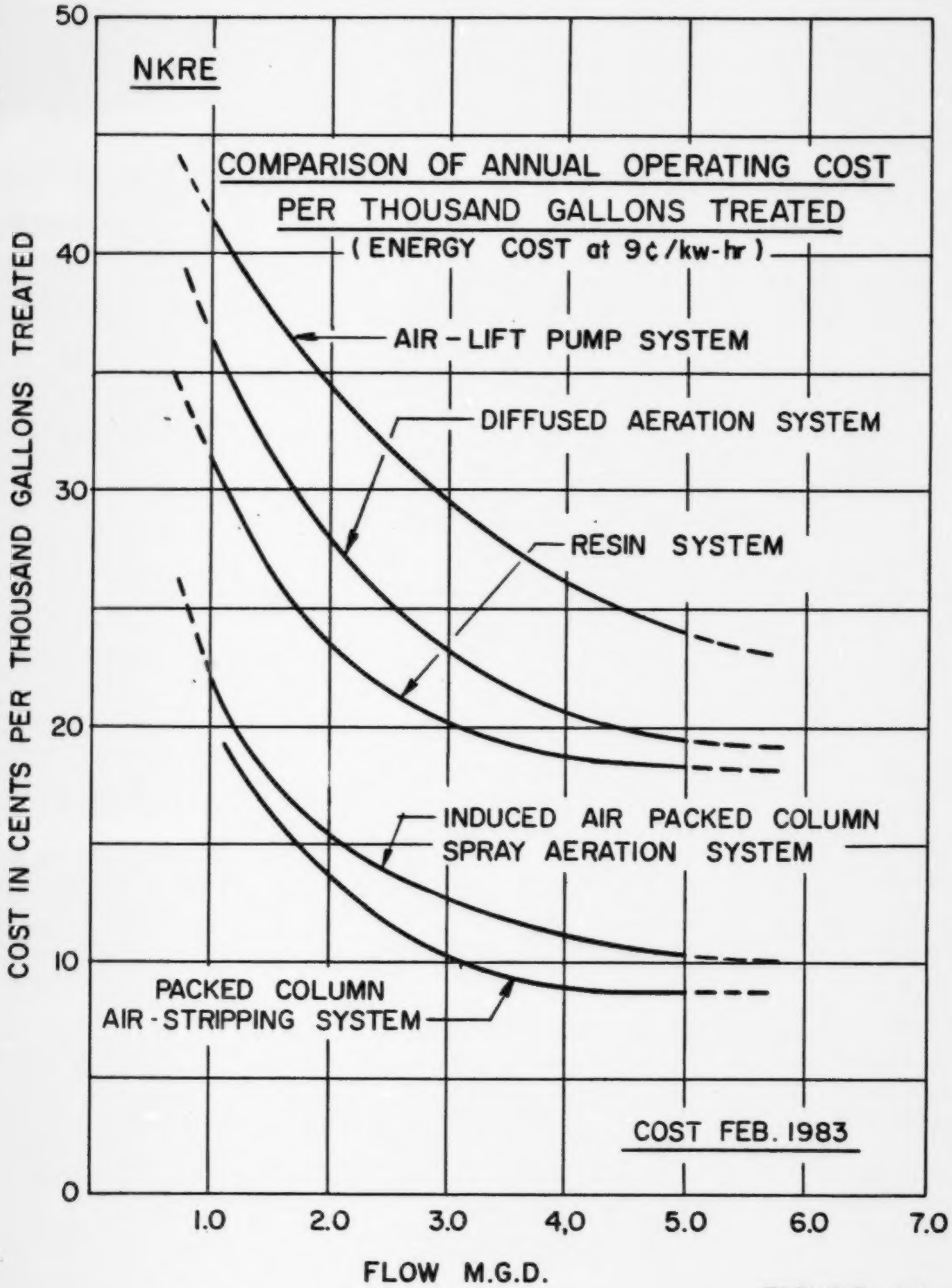

NKRE
COMPARISON OF ANNUAL OPERATING COST
PER THOUSAND GALLONS TREATED
(ENERGY COST at 9¢/kw-hr)
AIR-LIFT PUMP SYSTEM
DIFFUSED AERATION SYSTEM
RESIN SYSTEM
INDUCED AIR PACKED COLUMN
SPRAY AERATION SYSTEM
PACKED COLUMN
AIR-STRIPPING SYSTEM
COST FEB. 1983
COST IN CENTS PER THOUSAND GALLONS TREATED
0
10
20
30
40
50
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 64

PHASE III REPORT:

APPENDIX A
PHASE III WORK PLAN
AND
MODIFICATION

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REMOVAL OF ORGANIC CONTAMINANTS
FROM DRINKING WATER SUPPLY
AT
GLEN COVE, N.Y.

Phase III
WORK PLAN

Prepared by:

Nebolsine Kohlmann Ruggiero Engineers, P.C.
Consulting Engineers
New York, N.Y.

U.S. EPA Cooperative Agreement No. CR 806355-02

Project Officer:

Walter A. Feige
Drinking Water Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
DRINKING WATER RESEARCH DIVISION
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

October 23, 1981

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I. INTRODUCTION

The City of Glen Cove, New York, has several of its wells closed due to organic contamination, particularly by trichloroethylene, tetrachloroethylene and cis-1,2-dichloroethylene. Since this contamination is a nationwide problem, the U.S. EPA was interested and consequently funded a research project under a Cooperative Agreement (CR 806353-01) in 1978 to study methods for reducing the contaminants to acceptable levels.

Results of the initial research project are presented in report number EPA-600/2-80-198 titled "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase I". These results demonstrated success in removing contaminants by aeration and adsorption, and warranted extending the project for a second phase which was completed in March of 1981. The report on this second phase, which is presently in draft form, again indicated the desirability of extending this project for a third phase to further develop the treatment technologies and to evaluate system treatment utilizing more than one treatment technology. The third phase extension was approved by the U.S. EPA in July of 1981. This work plan presents the approach which will be utilized in the Phase III testing.

II. PHASE III TESTING

A. General

The Phase III pilot plant testing program will be conducted over a ten-month period at Glen Cove's Carney Street well site. The treatment technologies to be tested include aeration, air stripping, adsorption by resin and carbon, and a combination of aeration and adsorption by resin. The complete pilot plant testing system is presented schematically on Figure 1. All required water analyses will be performed on site using equipment previously purchased for this project.

B. Aeration and Air Stripping Studies

The aeration and air stripping studies will be performed using three separate systems: diffused column aeration, spray aeration column and air-lift pump. The three systems are designed to allow variation in air to water ratios and are to work independently of each other.

1. Diffused Column Aeration

The same counter-current diffused aeration column utilized

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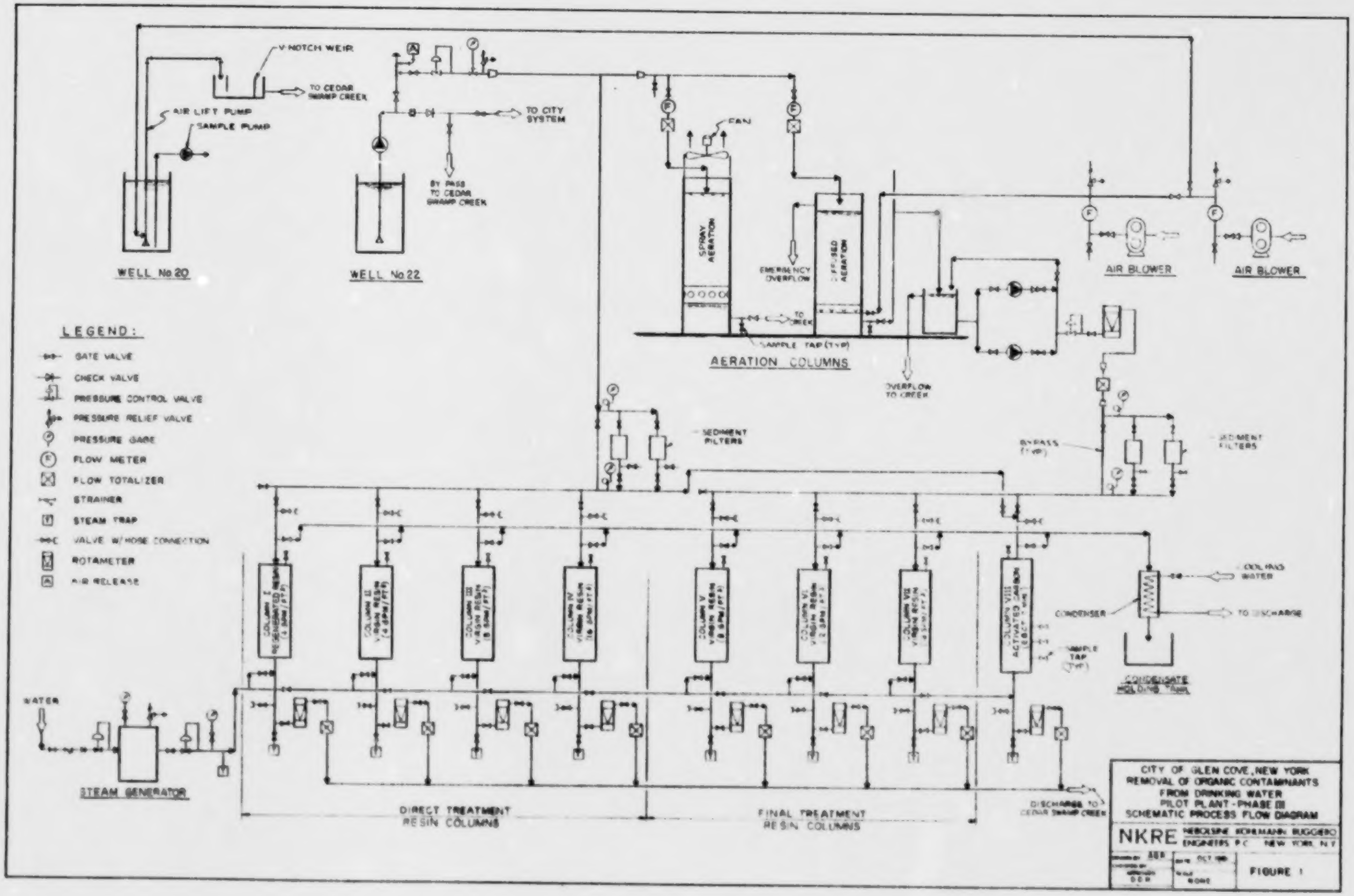

V-NOTCH WEIR
TO CEDAR SWAMP CREEK
AIR LIFT PUMP
SAMPLE PUMP
WELL No 20
TO CITY SYSTEM
BY PASS TO CEDAR SWAMP CREEK
WELL No 22
FAN
SPRAY AERATION
EMERGENCY OVERFLOW
DIFFUSED AERATION
TO CREEK
SAMPLE TAP (TYP)
AERATION COLUMNS
OVERFLOW TO CREEK
AIR BLOWER
AIR BLOWER
LEGEND:
GATE VALVE
CHECK VALVE
PRESSURE CONTROL VALVE
PRESSURE RELIEF VALVE
PRESSURE GAGE
FLOW METER
FLOW TOTALIZER
STRAINER
STEAM TRAP
VALVE W/HOSE CONNECTION
ROTAMETER
AIR RELEASE
SEDIMENT FILTERS
BYPASS (TYP)
SEDIMENT FILTERS
COLUMN I REGENERATED RESIN (4 GPM/FT³)
COLUMN II VIRGIN RESIN (4 GPM/FT³)
COLUMN III VIRGIN RESIN (8 GPM/FT³)
COLUMN IV VIRGIN RESIN (16 GPM/FT³)
COLUMN V VIRGIN RESIN (8 GPM/FT³)
COLUMN VI VIRGIN RESIN (2 GPM/FT³)
COLUMN VII VIRGIN RESIN (4 GPM/FT³)
COLUMN VIII ACTIVATED CARBON (8 GPM/FT³)
COOLING WATER
CONDENSER
TO DISCHARGE
SAMPLE TAP (TYP)
CONDENSATE HOLDING TANK
WATER
STEAM GENERATOR
DIRECT TREATMENT RESIN COLUMNS
FINAL TREATMENT RESIN COLUMNS
DISCHARGE TO CEDAR SWAMP CREEK
CITY OF GLEN COVE, NEW YORK
REMOVAL OF ORGANIC CONTAMINANTS
FROM DRINKING WATER
PILOT PLANT - PHASE III
SCHEMATIC PROCESS FLOW DIAGRAM
NKRE
NEBOLSINE KOHLMANN RUGGIERO
ENGINEERS P.C. NEW YORK, N.Y.
DATE OCT 1981
SCALE NONE
FIGURE 1

in Phases I and II will be used in the testing of diffused aeration. The column will again be operated at a constant flow rate of 28 gallons per minute which will enter the top of the column. Air will be supplied at the base of the column through air spargers at a rate to produce the desired air to water ratio. The detention time may also be varied to change this ratio. The major difference between Phase III diffused column aeration studies and those performed during Phases I and II is that the Phase III tests will run continuously for twenty-four hours per day. A portion of the water treated in the aeration column will be pumpted to resin columns for further removal of contaminants. The air to water ratio utilized for the initial portion of Phase III will be 5 to 1. Variation of this ratio will be based on the results obtained during the first months of Phase III testing.

2. Spray Aeration

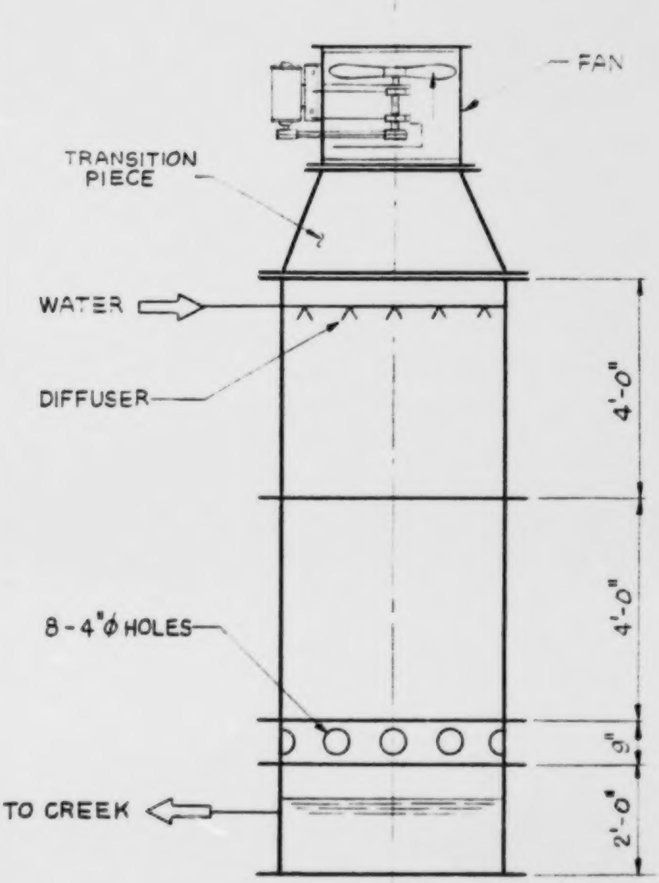
Spray aeration will be tested in a column similar to that utilized for the diffused aeration studies. The water will enter the top of the column through a spray nozzle system and be directed downward. Air will be induced through openings at the bottom of the column utilizing an induced draft fan located at the top of the column, as shown in Figure 2. The air and water will flow in counter current directions. The fan to be utilized will be of the constant speed type producing approximately 2500 cubic feet per minute (CFM) of air, therefore the air to water ratio will be controlled by the volume of water applied. This system will be operated during sampling days only and run for sufficient periods of time to produce stable conditions before the samples are taken.

3. Air-lift Pumping

An air-lift pumping system, as shown on Figure 3, installed in Well No. 20, will be tested to evaluate the feasibility of removing the contaminants by the air utilized to lift the water from the well in the air-lift pump system. The system has been designed to pump between 20 to 50 gpm utilizing a blower which provides approximately 100 CFM of air. This system will produce an air to water ratio at 50 gpm of slightly greater than 10 to 1. This ratio will be varied by either reducing the air supply or changing the flow by altering the length of the air pipe inside the eductor pipe in the well. This system will be operated in the same manner as the spray aeration system, only during the day of sampling.

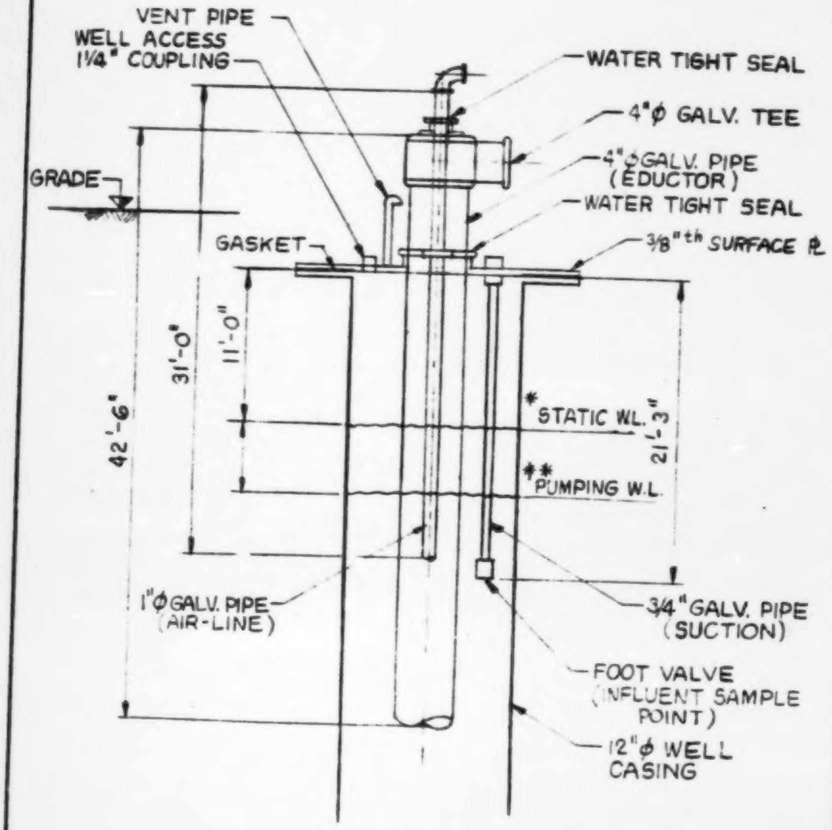
C. Resin Systems

This phase of resin testing will again utilize Rohm and Haas Ambersorb XE 340 ^{R}. The phase will evaluate or determine:


FAN
TRANSITION PIECE
WATER
DIFFUSER
4'-0"
4'-0"
8-4"ϕ HOLES
9"
TO CREEK
2'-0"

AERATION COLUMN

FIG 2


VENT PIPE
WELL ACCESS
1¼" COUPLING
WATER TIGHT SEAL
4"ϕ GALV. TEE
4"ϕ GALV. PIPE (EDUCTOR)
WATER TIGHT SEAL
GRADE
GASKET
3/8"th SURFACE ℞
31'-0"
11'-0"
42'-6"
*STATIC W.L.
**PUMPING W.L.
21'-3"
1"ϕ GALV. PIPE (AIR-LINE)
3/4" GALV. PIPE (SUCTION)
FOOT VALVE (INFLUENT SAMPLE POINT)
12"ϕ WELL CASING

AIR LIFT PUMP

NOTES:

* STATIC WATER LEVEL } WITH WELL #22 PUMP RUNNING
** PUMPING WATER LEVEL } APPROX. 9'-6" INFLUENCE
AIR & EDUCTOR PIPES SETTINGS ADJUSTABLE

FIG. 3

the maximum hydraulic loading possible, the use of resin as a final treatment after pretreatment by aeration, and will further develop the steam regeneration method. The resin columns will be the same as those utilized in Phase II having a 4-inch diameter and a height of 2.2 feet. Resin depth in each column will be 2 feet and the mode of operation will consist of downflow water application with upflow steam regeneration. Testing will be divided into two parts: the testing of adsorption by resin on the water directly from the contaminated well, and the testing of adsorption by resin on water pretreated by diffused aeration.

1. Direct Treatment

The water from Well No. 22 will be delivered directly to four resin columns operating in parallel. These columns are identified as I, II, III and IV. All columns except Column I will contain virgin resin while Column I will contain resin which was utilized in Phases I and II. Columns I and II will operate at an application rate of 4 gpm/ft3 (0.42 Lpm/m3), or a flow rate of 42 gallons per hour. The flow rate to Column III will be 84 gallons per hour producing an application rate of 8 gpm/ft3 (0.84 Lpm/m3) and Column IV will have an application rate of 16 gpm/ft3 (1.68 Lpm/m3) and a flow rate of 168 gallons per hour. These columns will be operated continually and should produce various breakthrough times indicating the effects of the different hydraulic loadings. Column I, with two feet (m) which has been used since the beginning of the project, is in place to evaluate the effects of successive regeneration.

2. Final Treatment

After treatment by diffused aeration, the treated water will be pumped to three resin columns designated Columns V, VI and VII. These columns will be utilized to evaluate the use of resin for final treatment after pretreatment by aeration and to determine the optimum hydraulic loading. Columns V, VI and VII will be operated at application rates of 8, 12 and 16 gpm/ft3 (0.84, 1.26, and 1.68 Lpm/m3) respectively. As for the other resin columns, these columns will be operated continuously.

3. Resin Regeneration

Resin regeneration will follow the procedure utilized in Phase II and no additional equipment will be required for the regeneration in this phase. Cis-1,2,dichloroethylene or the sum of the organic contaminants will be utilized as the indicator for regeneration. The major intent for the regeneration test in this phase is to: determine the optimum volume of steam necessary for regeneration, determine the proper steam application rate, and determine the proper handling and disposal of the steam condensate. The handling of steam condensate by the superloading method tried in Phase II will be the first approach tried in this phase.

D. Activated Carbon

One six-foot high column will be filled with four feet of activated carbon. The major purpose of the testing of activated carbon in this phase is to evaluate the wave front of contamination through the carbon bed. To accomplish this, sample taps have to be placed at one-foot intervals in the carbon bed. Samples will be taken periodically at these taps to determine the penetration of contaminants into the carbon bed. This column will operate at an empty bed contact time of seven (7) minutes having a flow rate of 21 gallons per hour. As all adsorption testing units, this column will operate continuously and will receive water directly from contaminated well No. 22.

E. Combined Treatment System

During Phase II it became apparent that an ideal system to remove contaminants from groundwater may be a systems approach utilizing aeration to efficiently strip contaminants to levels lower than present in the groundwater, and then final treating or polishing the water by resin adsorption. This approach will be evaluated by utilizing the testing data developed by the diffused aeration column and the results of the resin columns utilized for final treatment.

F. Sampling and Analysis

All analyses will be performed on the equipment at the pilot plant site in Glen Cove which was purchased for this project in Phase I. Quality Control and Assurance will be maintained using the procedure described in Attachment A. Also presented in Attachment A is the sampling procedure which will be followed throughout the field portion of Phase III.

All treatment processes will be sampled twice weekly during the beginning of Phase III. As the systems become more predictable, the sampling frequency may be decreased to a once weekly schedule. Each sampling day will include one sample from Well No. 22 which is to be utilized as influent for all testing processes except the air-lift pump system, effluent samples from all resin columns and both aeration columns, and a sample from the upper tap on the activated carbon column. The sample tap on the activated carbon column will be lowered when contamination has penetrated to the tap being utilized.

Since the air-lift pump is operating on a separate well, No. 20, a sampling device has been installed to sample the water below the point of air induction outside the eductor pipe. This will be utilized as influent to the air-lift pumping system and will be sampled each sampling day along with the pump discharge.

All samples will be analyzed for the four contaminants tested in Phases I and II, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene. Also, water exposed to the atmosphere will be analyzed periodically for suspended solids.

In addition to water analysis, the air discharging from the aeration columns will be analyzed for the same contaminants on approximately four (4) separate dates during the testing program. The ambient air will also be analyzed on these occasions. Air will also be sampled over the tank that accepts the water discharge from the air-lift pump.

In addition to the previously described water analyses, other laboratory analyses will be performed as needed to determine mass transfer coefficients for the aeration systems, and to evaluate whether the treatment systems have any effect on the bacteriological content of the water.

ATTACHMENT A

QUALITY ASSURANCE, QUALITY CONTROL (QA/QC) FOR GLEN COVE

The purpose of a QA/QC program is to make sure that the results being reported are within the accepted range of variability from the actual value. For this purpose, a number of steps are taken:

1. The purest chemicals available are used for standards.
2. From these, high concentration standards (2-20 g/L) for each pollutant in question are made. Fresh high concentration standards are constituted every other month.
3. Low concentration standard (1-200 mg/L) containing all the pollutants in question in ratios similar to those found in samples to be analyzed are formulated every two weeks.
4. All standard solutions use the highest quality methanol as solvent. Similarly, distilled water which has been passed through activated carbon and then purged with helium and kept under a helium atmosphere is used to make the final dilution of standards for analysis.
5. All standards to be used are analyzed at least in duplicate. Agreement of peak areas must be within 10% for duplicates. The values should not vary greatly from day to day.
6. The area of a sample pollutant must be within a factor of two of a standard (-50%, +100%). If a sample peak area falls between two standard concentrations whose areas are known, the pollutant's area is calculated by interpolation.

ATTACHMENT A (Continued)

SAMPLING PROCEDURE

All samples should be collected in duplicate.

LIQUIDS

Vials: Screw cap glass vials with teflon-faced silicone septum. Size 25 ml.

1) Slowly fill the vial to overflowing.
2) Carefully set the container on a level surface. There should be a convex meniscus rising above the lip of the vial.
3) Place the septum, teflon side down, on the convex sample meniscus.
4) Seal the sample with the screw cap.
5) Invert the vial and lightly tap the lid on a solid surface. The absence of entrapped air bubbles indicates a proper seal.
6) If bubbles are present, open the bottle, add more sample, and reseal. Return to step 5.
7) When no bubbles are present, label the sample vial using a waterproof label* and water proof ink.
8) If samples are not to be analyzed immediately, they should be refrigerated.

* The label should show: sample number, date of sampling, sampling point, preservative added (if any), sampler.

NKRE NEBOLSINE KOHLMANN RUGGIERO ENGINEERS, P.C.

TECHNICAL MEMORANDUM

Subject : Modifications to Phase III Work Plan for the Glen Cove Project U.S. EPA No. CR 806355-02

Date: April 7, 1982

Introduction

The Phase III work plan dated October 23, 1981 requires modifications due to the unsuitability of the new Ambersorb® XE-340 resin supplied by Rohm and Haas for the operations during this phase. The determination of the problem and the fact that resin was causing the problem consumed about five months of our project time. Based on the time delay and data determined during this period the modifications to the work plan indicated in this technical memorandum are required.

Phase III Testing To Date

The Phase III test equipment started operation on October 14, 1981 in accordance with the procedure outlined in the Phase III work plan. By early December 1981 it was evident that the new XE 340 resin was not performing in the same manner as the XE 340 resin utilized in Phases I and II and that early breakthrough was occurring. Due to electrical problems at the Glen Cove site it was impossible to attempt any solution to the problem until the latter part of January 1982.

The first attempt to determine the problem was to regenerate three columns I, II and V with steam and return them to service and to send samples of both the resin, that used in Phases I and II and that used in Phase III, to the manufacturer Rohm and Haas for evaluations by isotherms. The isotherms indicated that the capacity of both resins were nearly identical. However, by late February 1982 the analyses indicated premature breakthrough of the Phase III resin.

Since the isotherms indicated that the Phase III resin was nearly equal in capacity to that used in Phases I and II, it was believed that new contaminants in the well may have caused the premature breakthrough. To evaluate this theory samples from the well were taken and sent to the U.S. EPA laboratory and another EPA contractual lab for complete analysis, samples of the resin were again analyzed by Rohm and Haas and columns II, III and VII were cleaned and fresh resin installed. Column II was refilled with resin supplied for Phase III, while columns III and VII were refilled with resin used in Phases I and II. The results of the water analyses, which are contained in the attached letter, indicated that no appreciable difference in water quality was observed between Phase III and Phases I and II. By the second half of March 1982 it was evident that the resin originally used in Phases I and II was performing as expected and the resin supplied for Phase III was again indicating premature breakthrough. The tests by the manufacturer indicate that the resin for Phase III had larger particles than specified and therefore was not performing as expected. Such kinetic differences were not evident from the analyses performed in the manufacturer's laboratories. A copy of the letter from Rohm and Haas reporting the results of their tests is attached.

New Resin Evaluation

The testing program at Glen Cove was continued with new resin, supplied by Rohm and Haas, to insure that its performance was as expected and in line with that from Phases I and II. The procedure used is as follows:

1. Clean columns II, IV, V and VI and install newly supplied resin.

2. The columns were operated at the flow rates indicated in the following table.

Column No.	Resin Used	Flow Rate	Source of Influent
I	Regenerated Phases I and II	4 gpm/ft^3	Well
II	Newly supplied	4 gpm/ft^3	Well
III	Virgin Phases I and II	4 gpm/ft^3	Well
IV	Newly supplied	8 gpm/ft^3	Well
V	Newly supplied	4 gpm/ft^3	Effl. from Diff. Aer. Col.
VI	Newly supplied	12 gpm/ft^3	Effl. from Diff. Aer. Col.
VII	Virgin Phases I and II	4 gpm/ft^3	Effl. from Diff. Aer. Col.

Evaluation of the new resin started on March 31, 1982. The six weekly analyses to date indicate that the new resin is performing similarly to that used in the previous two phases. Based on this data it was determined that the resin presently being used (newly supplied) is proper for this program and the program should continue as indicated in the Phase III work plan with necessary modification to this work plan. Until the modifications in the work plan procedure can be made, the testing will continue as indicated in the previous table.

Phase III Continuation

Reviewing the data collected during the evaluation period of the newly supplied resin and that collected during the beginning period of Phase III it was determined that modification to the work plan and a five-month extension of this program are necessary. Based on a discussion and meeting (attached memorandum of May 11, 1982) with Rohm and Haas to evaluate their projection for the resin future, it was determined that there are no present plans to begin full scale production of the Ambersorb® XE-340 resin. This is based on Rohm and Haas projection of the market for this resin. Since the marketing of this resin is influenced by the need in water supply and this need can change drastically depending on the required drinking water quality or MCL, the full-scale production of this resin may be feasible in the future. Based on these facts it was mutually decided between U.S. EPA, the City of Glen Cove and NKRE to emphasize the development of the aeration technology while continuing the testing of the resin over the rest of this phase. This will provide necessary design data to communities requiring treatment of drinking water to levels achievable by aeration and develop the basis for the design of resin systems when needed in the future.

A. Aeration System

1. Spray Aeration Column

The data to date has indicated that the present spray distribution system is not operating properly and the majority of water is running down the side of the column. This does not allow the proper contact of air and water. The spray header using spray nozzles will be replaced with a spray header distributing the water with simple holes. After this method is evaluated at several air to water ratios a new nozzle system will be installed and evaluated. Research will be continued to determine the best method of water spray distribution. Other methods determined feasible will also be tested.

2. Diffused Aeration Column

The diffused aeration column will be run at air to water ratios which will reduce the contaminants in the water to levels acceptable under present New York State guidelines.

This is a variation from the original Phase III work plan, since the original plan was to remove the bulk of the organics with diffused aeration and then remove the remainder on the resin columns. The polishing by resin will still be evaluated during the Phase III operation.

3. Air Lift Pumping

The testing of the air lift pumping will continue as indicated in the Phase III work plan.

The effect of the aeration devices on the ambient air will be evaluated through a series of air sampling and analyses. Also the effect of the ambient air on the water will be evaluated by running analyses to determine suspended solids and particles in the water.

B. Resin Columns

The new resin evaluation indicated the acceptability of this resin. Therefore the Phase III continuation will use this resin in the test columns except for Column I which contains resin from the beginning of this project.

Fresh resin will be installed in Columns III, IV, VI and VII, and the columns will be run at hydraulic rates as indicated in the following table which were selected after evaluation of previous analytical data. These flow rates are designed to determine the optimum hydraulic loading and the effect of pre-aeration on the life of the resin.

Column No.	Resin Used	Flow Rate	Source of Influent
I	Regenerated Phases I and II	4 gpm/ft^3	Well
II	Newly supplied	4 gpm/ft^3	Well
III	Newly supplied	2 gpm/ft^3	Well
IV	Newly supplied	6 gpm/ft^3	Well
V	Newly supplied	4 gpm/ft^3	Effl. from Diff. Aer. Col.
VI	Newly supplied	6 gpm/ft^3	Effl. from Diff. Aer. Col.
VII	Newly supplied	8 gpm/ft^3	Effl. from Diff. Aer. Col.

The resin in Column I has been used in the two previous phases. This resin has been regenerated about 7 times and has been transferred from one column to another. The actual flow application for Phase I was in a downward mode with upflow steam regenerated. This was reversed in Phase II to an upward flow application and a downward flow regeneration. The system was returned to a downward flow application and upward steam regeneration for Phase III. The purpose of this column is to determine the life of the resin and to evaluate the multiple regeneration effects. This resin will be regenerated using a solvent to evaluate the manufacturer's contention that solvent regeneration will return the resin to a near virgin state. This evaluation will be accomplished by regenerating with a solvent, returning the resin to operation and comparing the results to those obtained during Phase I.

All other testing systems will operate as described in the Phase III work plan. For reference, a schematic flow diagram of the Phase III testing system is attached to this Technical Memorandum.

PHASE III REPORT:

APPENDIX B

PHASE III PILOT PLANT RESULTS

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TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
01	2	10/16/81	INF-201	71	2.3	185	42		
			I-ACE-201	19	<0.5	67	137	5:1	
			I-RCE-201	<0.5	<0.5	<0.5	<0.5		
			II-RCE-201	<0.5	0.5	0.5	0.9		
			III-RCE-201	4.1	0.8	3.1	1.8		
			IV-RCE-201	7.7	1.8	9.3	12		
			V-RCE-201	0.8	<0.5	0.8	1.3		
			VI-RCE-201	4.8	0.7	4.8	21		
			VII-RCE-201	8.3	N.M.[1]	7.9	1.3		
02	6	10/20/81	INF-202	78	2.8	197	151		
			I-ACE-202	27	<0.5	32	1.7	5:1	
			I-RCE-202	3.4	1.5	2.8	4.3		
			II-RCE-202	3.9	2.9	7.3	9.4		
			III-RCE-202	21	1.7	51	162		
			IV-RCE-202	40	2.6	57	36		
			V-RCE-202	2.6	<0.5	2.4	1.0		
			VI-RCE-202	8.1	1.1	8.9	65		
			VII-RCE-202	19	N.M.	21	105		
			o-INF-202[2]	28	N.M.	80	8.2		
			o-ACE-202[2]	23	0.8	58	2.3	15:1	
03	8	10/22/81	INF-203	75	2.8	185	39		
			I-ACE-203	37	N.M.	36	2.8	5:1	
			I-RCE-203	1.0	<0.5	1.1	1.2		
			II-RCE-203	2.7	1.5	1.3	1.7		
			III-RCE-203	22	2.0	23	9.2		
			IV-RCE-203	47	2.4	70	180		
			V-RCE-203	4.5	<0.5	4.2	1.7		
			VI-RCE-203	12	0.5	13	1.8		
			VII-RCE-203	19	0.6	19	2.6		
			o-INF-203	31	0.9	103	5.8		
			o-ACE-203	30	N.M.	66	2.3	19:1	
04	13	10/27/81	INF-204	75	2.7	184	41		
			I-ACE-204	22	N.M.	40	1.5	5:1	
			I-RCE-204	3.5	2.4	3.2	3.2		
			II-RCE-204	9.1	1.3	7.5	7.1		
			III-RCE-204	38	2.9	38	12		
			IV-RCE-204	62	3.1	94	25		
			V-RCE-204	9.1	N.M.	8.9	1.9		
			VI-RCE-204	18	0.7	20	3.4		
			VII-RCE-204	22	0.7	24	3.8		
			o-INF-204		(sample not taken)				
			o-ACE-204	25	N.M.	62	2.1	20:1	
05	15	10/29/81	INF-205	72	2.8	182	34		
			I-ACE-205	28	N.M.	35	1.2	5:1	
			I-RCE-205	14	2.5	11	7.0		
			II-RCE-205	16	2.0	18	11		
			III-RCE-205	51	2.8	69	17		
			IV-RCE-205	71	3.7	106	27		
			V-RCE-205	9.7	N.M.	7.9	1.9		
			VI-RCE-205	18	0.7	20	3.2		
			VII-RCE-205	22	0.7	24	3.8		
			o-INF-205		(sample not taken)				
			o-ACE-205	24	N.M.	59	2.2	17:1	

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TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
06	20	11/3/81	INF-206	71	2.6	164	35		
			I-ACE-206	29	N.M.	36	1.3	5:1	
			I-RCE-206	12	1.8	5.7	4.8		
			II-RCE-206	25	2.3	29	14		
			III-RCE-206	57	2.8	73	18		
			IV-RCE-206	69	3.1	101	24		
			V-RCE-206	12.9	N.M.	9.5	1.5		
			VI-RCE-206	19	0.7	20	2.4		
			VII-RCE-206	22	0.7	24	4.6		
			o-INF-206	27	1.7	135	9.3		
			o-ACE-206	26	N.M.	65	1.7		Weir not working
07	22	11/5/81	INF-207	81	2.9	190	40		
			I-ACE-207	27	N.M.	34	0.9	5:1	
			I-RCE-207	16	1.7	18	13		
			II-RCE-207	21	1.8	15	6.8		
			III-RCE-207	60	2.9	78	18		
			IV-RCE-207	78	4.4	106	36		
			V-RCE-207	14	N.M.	11	3.4		
			VI-RCE-207	20	0.7	20	5.2		
			VII-RCE-207	23	0.7	24	4.1		
			o-INF-207	33	1.9	142	12		
			o-ACE-207	26	N.M.	67	2.0	22:1	
08	26	11/9/81	INF-208	90	2.9	182	34		
			I-ACE-208	30	N.M.	33	0.7	5:1	
			I-RCE-208	16	1.1	9.0	4.5		
			II-RCE-208	29	2.3	24	10		
			III-RCE-208	61	3.3	81	21		
			IV-RCE-208	76	3.3	106	25		
			V-RCE-208	14	N.M.	10	1.7		
			VI-RCE-208	21	N.M.	21	2.7		
			VII-RCE-208	25	N.M.	24	3.2		
			o-INF-208	37	2.6	149	11		
			o-ACE-208	25	N.M.	65	1.1	18:1	
09	29	11/12/81	INF-209	93	3.0	187	34		
			I-ACE-209	27	N.M.	35	0.8	5:1	
			I-RCE-209	22	1.5	13	6.4		
			II-RCE-209	34	1.9	30	11		
			III-RCE-209	66	4.0	83	19		
			IV-RCE-209	74	3.2	106	22		
			V-RCE-209	15	N.M.	10	1.5		
			VI-RCE-209	20	N.M.	19	2.4		
			VII-RCE-209	23	N.M.	22	2.8		
			o-INF-209	41	2.9	160	11		
			o-ACE-209	18	0.6	46	2.3	16:1	
10	33	11/16/81	INF-210	96	3.1	189	37		
			I-ACE-210	43	0.9	50	7.8	5:1	
			I-RCE-210	28	1.7	16	7.2		
			II-RCE-210	42	2.4	52	17		
			III-RCE-210	67	2.9	84	17		
			IV-RCE-210	81	3.4	112	26		
			V-RCE-210	25	0.7	20	3.2		
			VI-RCE-210	31	1.0	33	4.9		
			VII-RCE-210	35	1.1	37	6.0		
			o-INF-210	41	2.8	163	11		
			o-ACE-210	24	0.7	62	3.1	17:1	

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
11	35	11/18/81	INF-211	100	3.3	197	40		
			I-ACE-211	42	0.8	50	4.5	5:1	
			I-RCE-211	40	2.8	25	11		
			II-RCE-211	50	2.7	65	21		
			III-RCE-211	66	2.5	109	21		
			IV-RCE-211	91	2.9	160	32		
			V-RCE-211	20	N.M.	21	2.0		
			VI-RCE-211	31	<0.5	40	3.9		
			VII-RCE-211	34	0.8	49	5.8		
			o-INF-211	40	2.7	161	11		
			o-ACE-211	23	0.8	60	3.1	16:1	
12	41	11/24/81	INF-212	99	3.2	194	42		
			I-ACE-212	38	0.8	67	10	5:1	
			I-RCE-212	46	2.3	18	7.0		
			II-RCE-212	51	2.4	41	12		
			III-RCE-212	71	2.6	116	31		
			IV-RCE-212	98	3.1	172	38		
			V-RCE-212	19	<0.5	19	2.0		
			VI-RCE-212	40	0.8	56	7.5		
			VII-RCE-212	47	1.0	69	10		
			o-INF-212	41	2.8	158	31		
			o-ACE-212	26	1.3	65	3.6	15:1	
13	51	12/4/81	INF-213	93	2.4	175	36		
			I-ACE-213	53	1.1	62	11	5:1	
			I-RCE-213	59	2.4	40	29		
			II-RCE-213	57	2.7	61	19		
			III-RCE-213	78	2.8	122	25		
			IV-RCE-213	101	3.2	161	38		
			V-RCE-213	25	0.5	28	3.4		
			VI-RCE-213	43	1.1	58	28		
			VII-RCE-213	47	1.2	69	73		
			o-INF-213	42	2.9	161	18		
			o-ACE-213	27	1.3	74	43		
14	57	12/10/81	INF-214	101	33	184	51		Weir not working
			I-ACE-214	55	1.2	62	32	5:1	
			I-RCE-214	62	1.8	33	7.6		
			II-RCE-214	60	2.2	73	16		
			III-RCE-214	83	2.9	136	30		
			IV-RCE-214	98	3.0	161	37		
			V-RCE-214	37	0.9	43	6.2		
			VI-RCE-214	45	1.0	60	9.2		
			VII-RCE-214	51	1.0	69	11		
			o-INF-214		(sample not taken)				
			o-ACE-214		(sample not taken)				
15	65	12/18/81	INF-215	105	3.2	187	46		
			I-ACE-215		(sample not taken)				
			I-RCE-215	79	2.5	62	43		
			II-RCE-215	63	1.9	66	19		
			III-RCE-215	84	2.4	114	31		
			IV-RCE-215	88	2.8	141	34		
			V-RCE-215		(aerator not running)				
			VI-RCE-215		(aerator not running)				
			VII-RCE-215		(aerator not running)				
			o-INF-215		(sample not taken)				
			o-ACE-215		(sample not taken)				

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
16	71	12/24/81	INF-216	94	2.9	172	44		
			I-ACE-216		(sample not taken)			5:1	
			I-RCE-216	80	2.4	62	19		
			II-RCE-216	72	2.0	83	24		
			III-RCE-216	86	2.8	130	31		
			IV-RCE-216	96	2.8	142	35		
			V-RCE-216		(aerator not running)				
			VI-RCE-216		(aerator not running)				
			VII-RCE-216		(aerator not running)				
			o-INF-216		(sample not taken)				
			o-ACE-216		(sample not taken)				
17	76	12/29/81	INF-217	95	2.9	173	45		
			I-ACE-217		(sample not taken)			5:1	
			SACE-217[3]	29	0.9	53	12	528:1	
			I-RCE-217	90	2.1	63	16		
			II-RCE-217	81	2.4	92	27		
			III-RCE-217	88	2.7	132	31		
			IV-RCE-217	89	2.5	126	29		
			V-RCE-217		(aerator not running)				
			VI-RCE-217		(aerator not running)				
			VII-RCE-217		(aerator not running)				
			o-INF-216		(sample not taken)				
			o-ACE-217		(sample not taken)				
18	83	01/05/82	INF-218	96	2.8	175	45		
			I-ACE-218	46	0.9	57	8.8	5:1	
			SACE-218	30	1.0	55	12	514:1	
			I-RCE-218	95	2.5	82	24		
			II-RCE-218	86	2.5	97	28		
			III-RCE-218	91	2.7	135	33		
			IV-RCE-218	94	2.8	144	36		
			V-RCE-218	31	0.7	29	5.6		
			VI-RCE-218	37	0.9	43	8.4		
			VII-RCE-218	43	1.0	50	9.8		
			o-INF-218		(sample not taken)				
			o-ACE-218		(sample not taken)				
19	89	01/11/82	INF-219	105	2.3	202	50		
			I-ACE-219	51	0.6	59	9.0	5:1	
			SACE-219		(sample not taken)				
			I-RCE-219	96	2.0	70	19		
			II-RCE-219	81	1.9	91	24		
			III-RCE-219	94	2.2	163	37		
			IV-RCE-219	97	2.3	181	43		
			V-RCE-219	44	0.5	39	6.3		
			VI-RCE-219	44	0.5	47	8.0		
			VII-RCE-219	45	0.6	50	8.7		
			o-INF-219		(sample not taken)				
			o-ACE-219		(sample not taken)				
20	96	01/18/82	INF-220	97	2.3	188	43		
			I-ACE-220	59	0.9	72	14	5:1	
			SACE-220		(sample not taken)				
			I-RCE-220	99	1.6	77	16		
			II-RCE-220	84	1.6	98	22		
			III-RCE-220	98	1.8	137	32		
			IV-RCE-220	106	2.2	173	40		
	5		CCI-220[4]	23	0.6	1.2	< 0.5		
	5		CC2-220[5]	NM	NM	NM	NM		
	96		V-RCE-220	50	0.7	48	8.5		
			VI-RCE-220	53	0.8	61	12		
			VII-RCE-220	54	0.8	64	12		
			o-INF-220		(sample not taken)				
			o-ACE-220	29	0.9	69	4.3		Manometer not working

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
21	103	01/25/82	INF-221	100	2.1	186	42		
			I-ACE-221	62	0.7	77	12	5:1	
			SACE-221	35	0.7	63	15	528:1	
			I-RCE-221	99	1.5	83	16		
			II-RCE-221	92	1.7	112	27		
			III-RCE-221	98	1.8	139	32		
			IV-RCE-221	103	2.0	155	34		
	13		CC1-221	96	1.2	8.4	<0.5		
	13		CC2-221	9.2	NM	NM	NM		
	103		V-RCE-221	50	0.7	47	7.4		
			VI-RCE-221	46	0.6	51	8.7		
			VII-RCE-221	55	0.8	67	11		
			o-INF-221	40	1.2	151	12		
			o-ACE-221	27	0.6	66	3.3		Manometer not working
Resin Column II regenerated from 1/27/82 to 1/28/82.									
22	110	02/01/82	INF-222	101	2.2	191	40		
			I-ACE-222	59	0.6	75	10	5:1	
			SACE-222	35	0.5	64	12	514:1	
			I-RCE-222	111	1.8	79	24		
	4		II-RCE-222	2.7	< 0.5	2.2	4.0		
	110		III-RCE-222	112	2.4	155	69		
	110		IV-RCE-222	106	2.4	183	36		
	19		CC1-222	128	1.5	41	0.8		
	19		CC2-222	70	0.9	NM	NM		
	110		V-RCE-222		(sample not taken)				
			VI-RCE-222	53	0.7	62	10		
			VII-RCE-222	58	0.8	69	14		
			o-RCE-222	36	1.4	133	8.4		
			o-ACE-222	19	< 0.5	56	3.0		Manometer not working
Resin Column V regenerated after superloading from 1/28/82 to 2/3/82. Resin Column I regenerated from 2/2/82 to 2/3/82									
23	117	02/08/82	INF-223	109	2.3	198	46		
			I-ACE-223	71	1.2	82	13	5:1	
			SACE-223	35	1.3	59	12		
	5		I-RCE-223	2.0	< 0.5	2.1	3.0		
	11		II-RCE-223	15	0.6	13	7.3		
	117		III-RCE-223	108	2.4	165	35		
	117		IV-RCE-223	110	2.4	186	36		
	26		CC1-223	125	1.4	39	<0.5		
	26		CC2-223	91	0.8	0.6	NM		
	5		V-RCE-223	1.8	< 0.5	1.8	1.5		
	117		VI-RCE-223	62	0.7	72	11		
	117		VII-RCE-223	64	0.8	78	12		
			o-INF-223		(sample not taken)				
			o-ACE-223	28	0.6	67	3.1		Manometer not working
24	125	02/17/82	INF-224	132	2.7	208	44		
			I-ACE-224	81	1.4	93	13	5:1	
			SACE-224	39	1.3	64	12	487:1	
	14		I-RCE-224	13	1.5	8.9	6.6		
	20		II-RCE-224	49	2.1	41	11		
			III-RCE-224		(analyses not performed)				
			IV-RCE-224		(analyses not performed)				
	35		CC1-224	152	1.4	93	1.2		
	35		CC2-224	144	0.9	0.7	<0.5		
	35		CC3-224[6]	81	1.3	0.7	<0.5		
	14		V-RCE-224	14	1.0	12	2.9		
			VI-RCE-224		(analyses not performed)				
			VII-RCE-224		(analyses not performed)				
	125		o-INF-224	46	1.4	150	11		
			o-ACE-224	31	0.7	66	3.0		Manometer not working

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
25	131	02/23/82	INF-225	123	2.5	202	40		
			I-ACE-225	87	1.5	105	15	5:1	
			SACE-225	40	1.4	65	20	544:1	
	20		I-RCE-225	18	0.9	13	6.7		
			II-RCE-225	(analyses not performed)					
			III-RCE-225	(analyses not performed)					
			IV-RCE-225	(analyses not performed)					
	41		CC1-225	135	1.3	125	1.6		
	41		CC2-225	166	1.0	1.3	< 0.5		
	41		CC3-225	123	0.5	N.M.	N.M.		
	20		V-RCE-225	17	1.2	14	4.3		
			VI-RCE-225	(analyses not performed)					
			VII-RCE-225	(analyses not performed)					
	131		o-INF-225	50	1.6	136	8.3		
			o-ACE-225	40	0.9	68	3.0		Manometer not working
Resin Column III filled with resin from Phases I and II on 2/25/82.									
Resin Column IV filled with resin from Phase III on 2/25/82.									
26	139	03/03/82	INF-226	131	2.7	214	45		
			I-ACE-226	85	1.8	137	20	5:1	
			SACE-226	39	1.4	65	13	560:1	
	28		I-RCE-226	32	1.2	18	8.2		
			II-RCE-226	(analyses not performed)					
	6		III-RCE-226	<0.5	<0.5	< 0.5	< 0.5		
	6		IV-RCE-226	28	1.5	25	13		
	49		CC1-226	145	1.3	166	2.9		
	49		CC2-226	177	1.2	5.6	N.M.		
	49		CC3-226	165	0.8	N.M.	N.M.		
	28		V-RCE-226	34	1.2	38	12		
			VI-RCE-226	(analyses not performed)					
			VII-RCE-226	(analyses not performed)					
	139		o-INF-226	50	1.6	136	8.6		
			o-ACE-226	40	0.9	68	3.1		Manometer not working
27	144	03/08/82	INF-227	131	2.7	211	44		
			I-ACE-227	89	1.9	140	21	5:1	
			SACE-227	40	1.4	65	13	544:1	
	33		I-RCE-227	46	1.5	26	11		
			II-RCE-227	(analyses not performed)					
	11		III-RCE-227	1.1	0.5	< 0.5	< 0.5		
	11		IV-RCE-227	52	2.1	55	20		
	54		CC1-227	139	1.3	170	3.2		
	54		CC2-227	185	1.3	10	< 0.5		
	54		CC3-227	176	1.0	N.M.	< 0.5		
	33		V-RCE-227	42	1.3	42	15		
			VI-RCE-227	(analyses not performed)					
			VII-RCE-227	(analyses not performed)					
	144		o-INF-227	55	2.0	149	9.8		
			o-ACE-227	39	0.9	70	3.2	16:1	
Resin Column VII filled with resin from Phases I and II on 3/15/82.									
28	155	03/19/82	INF-228	121	2.9	234	48		
			I-ACE-228	104	2.0	166	28	5:1	
			SACE-228	43	1.4	67	14	544:1	
	44		I-RCE-228	73	1.6	34	12		
			II-RCE-228	(analyses not performed)					
	22		III-RCE-228	2.1	1.1	< 0.5	< 0.5		
	22		IV-RCE-228	89	2.9	113	31		
	65		CC1-228	149	1.4	200	5.0		
	65		CC2-228	173	1.5	38	< 0.5		
	65		CC3-228	193	1.1	< 0.5	N.M.		

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
28	44		V-RCE-228	54	1.6	50	19		
			VI-RCE-228	(analyses not performed)					
	4		VII-RCE-228	<0.5	<0.5	<0.5	<0.5		
	155		o-INF-228	(sample not taken)					
			o-ACE-228	49	1.0	73	3.5	17:1	
29	159	03/23/82	INF-229	127	2.9	238	56		
			I-ACE-229	82	0.8	95	11	5:1	
			SACE-229	37	0.5	6.5	12	544:1	
	48		I-RCE-229	82	1.9	49	30		
			II-RCE-229	(analyses not performed)					
	26		III-RCE-229	4.6	1.2	< 0.5	< 0.5		
			IV-RCE-229	(analyses not performed)					
	69		CC1-229	169	1.5	224	9.6		
	69		CC2-229	174	1.6	58	N.M.		
	69		CC3-229	200	1.4	< 0.5	N.M.		
	48		V-RCE-229	55	1.4	47	13		
			VI-RCE-229	(analyses not performed)					
	8		VII-RCE-229	< 0.5	< 0.5	< 0.5	< 0.5		
	159		o-INF-229	47	1.0	137	7.8		
			o-ACE-229	43	0.9	70	3.4	17:1	
30	165	03/29/82	INF-230	132	3.1	253	51		
			I-ACE-230	94	1.0	119	15	5:1	
			SACE-230	37	0.6	68	12	685:1	
	54		I-RCE-230	94	2.0	69	32		
			II-RCE-230	(analyses not performed)					
	32		III-RCE-230	10	1.2	< 0.5	< 0.5		
			IV-RCE-230	(analyses not performed)					
	75		CC1-230	146	2.8	249	7.2		
	75		CC2-230	164	3.1	84	< 0.5		
	75		CC3-230	210	1.5	0.5	N.M.		
	54		V-RCE-230	55	1.5	46	13		
			VI-RCE-230	(analyses not performed)					
	14		VII-RCE-230	1.1	<0.5	<0.5	< 0.5		
	165		o-INF-230	57	1.2	148	8.6		
			o-ACE-230	44	0.6	73	3.7	40:1	

Resin Columns II, IV, V, and VI filled with fresh resin on 3/31/82.

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
31	172	04/05/82	INF-231	124	2.3	224	49		
			I-ACE-231	78	1.0	103	15	5:1	
			SACE-231	41	0.8	76	14	771:1	
	61		I-RCE-231	117	1.6	56	13		
	5		II-RCE-231	0.7	1.1	<0.5	< 0.5		
	39		III-RCE-231	23	1.6	0.6	< 0.5		
	5		IV-RCE-231	13	1.5	2.1	1.7		
	82		CC1-231	149	3.0	259	8.8		
	82		CC2-231	159	2.9	106	0.2		
	82		CC3-231	192	3.1	1.0	N.M.		
	5		V-RCE-231	< 0.5	<0.5	<0.5	< 0.5		
	5		VI-RCE-231	31	1.3	14	4.0		
	21		VII-RCE-231	5.8	<0.5	<0.5	< 0.5		
	172		o-INF-231	72	1.4	140	10		
			o-ACE-231	40	0.5	65	2.7	19:1	
32	179	04/12/82	INF-232	112	2.4	201	38		
			I-ACE-232	92	1.3	134	18	5:1	
			SACE-232	41	0.6	74	14	925:1	
	68		I-RCE-232	97	2.2	66	16		
	12		II-RCE-232	5.2	1.3	<0.5	< 0.5		
	46		III-RCE-232	27	1.7	1.3	0.5		
	12		IV-RCE-232	46	1.9	26	9.0		

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
32	12	04/12/82	VI-RCE-232	46	1.9	26	9.0		
	89		CC1-232	151	2.9	260	11		
	89		CC2-232	160	3.2	147	<0.5		
	89		CC3-232	189	3.2	5.7	<0.5		
	12		V-RCE-232	1.1	< 0.5	<0.5	<0.5		
	12		VI-RCE-232	53	1.4	44	8.9		
	28		VII-RCE-232	15	1.1	<0.5	<0.5		
	179		o-INF-232	67	1.3	142	8.6		
			o-ACE-232	39	0.5	69	3.1	19:1	
33	187	04/20/82	INF-233	130	2.5	210	50		
			I-ACE-233	99	2.1	121	21	5:1	
			SACE-233	39	0.6	70	13	925:1	
			I-RCE-233	142	2.3	63	13		
	20		II-RCE-233	24	2.0	3.0	1.5		
	54		III-RCE-233	57	2.2	3.5	<0.5		
	20		IV-RCE-233	90	2.1	66	16		
	97		CC1-233	150	2.9	262	16		
	97		CC2-233	156	3.2	196	<0.5		
	97		CC3-233	180	3.4	22	N.M.		
	20		V-RCE-233	6.0	0.5	<0.5	<0.5		
	20		VI-RCE-233	69	2.2	44	8.9		
	36		VII-RCE-233	22	1.2	<0.5	<0.5		
	187		o-INF-233	59	1.1	141	8.9		
			o-INF-233	47	0.6	71	3.5	23:1	
34	193	04/26/82	INF-234	132	2.3	208	42		
			I-ACE-234	91	1.0	102	14	5:1	
			SACE-234	41	0.6	72	21	925:1	
			I-RCE-234	138	1.4	60	15		
	26		II-RCE-234	37	1.5	6.1	2.8		
	60		III-RCE-234	72	1.6	3.5	0.8		
	26		VI-RCE-234	104	2.1	70	15		
	103		CC1-234	139	2.7	212	14		
	103		CC2-234	147	3.0	168	<0.5		
	103		CC3-234	177	3.6	30	N.M.		
	26		V-RCE-234	13	0.5	<0.5	0.7		
	26		VI-RCE-234	70	1.3	48	6.9		
	42		VII-RCE-234	25	0.6	<0.5	<0.5		
	193		o-INF-234	69	1.3	145	9.9		
			o-ACE-234	44	0.6	71	3.4	27:1	
35	200	05/03/82	INF-235	146	2.3	188	37		
			I-ACE-235	93	0.8	93	12	5:1	
			SACE-235	43	0.6	72	14	841:1	
			I-RCE-235	154	1.7	89	16		
	33		II-RCE-235	55	1.4	8.8	2.5		
	67		III-RCE-235	91	1.1	2.9	0.7		
	33		IV-RCE-235	119	1.5	91	19		
	110		CC1-235	146	2.0	216	16		
			CC2-235	160	2.3	206	0.6		
			CC3-235	181	2.6	65	<0.5		
	33		V-RCE-235	24	1.3	0.8	0.5		
	33		VI-RCE-235	68	0.7	50	7.0		
	49		VII-RCE-235	31	0.9	<0.5	<0.5		
	200		o-INF-235	73	1.3	137	9.9		
			o-ACE-235	54	0.6	71	3.0	50:1	Leak at side of weir

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1.1.1	Tri	Tetra	Ratio Air: Water	Remarks
36	207	05/10/82	INF-236	136	2.9	183	37		
			I-ACE-236	131	2.3	149	26	5:1	
			SACE-236	47	0.7	64	13	638:1	
			I-RCE-156	156	2.5	83	16		
	40		II-RCE-236	80	1.6	19	5.2		
	74		III-RCE-121	1.7	1.7	8.7	2.7		
	40		IV-RCE-236	126	1.4	83	18		
	117		CC1-236	128	1.9	210	16.6		
	117		CC2-236	128	2.2	224	0.6		
	117		CC3-236	145	2.5	98	N.M.		
	117		CC4-236[7]	151	2.5	1.3	N.M.		
	40		V-RCE-236	30	< 0.5	1.6	0.8		
	40		VI-RCE-236	86	1.5	6.3	7.9		
	56		VII-RCE-236	39	1.3	1.1	< 0.5		
	207		o-INF-236	68	2.1	139	8.3		
			o-ACE-236	54	0.7	65	3.0	51:1	Leak at side of weir
37	211	05/14/82	INF-237	119	3.0	216	38		
			I-ACE-237	74	0.9	69	8.7	5:1	
			SACE-237[8]	45	1.2	81	13		
			SACE-HR-237[9]	46	0.7	64	13	638:1	
			SACE-LR-237[10]	45	0.9	79	17	1849:1	
			I-RCE-237	131	1.6	103	19		
	44		II-RCE-237	69	1.3	17	4.4		
	78		III-RCE-237	104	1.4	79	1.1		
	44		IV-RCE-237	112	1.6	121	20		
	121		CC1-237	133	2.3	245	20		
	121		CC2-237	132	2.3	235	1.2		
	121		CC3-237	138	2.1	102	N.M.		
	121		CC4-217	140	1.9	3.2	< 0.5		
	44		V-RCE-237	31	1.2	5.7	1.3		
	44		VI-RCE-237	60	1.1	48	6.6		
	60		VII-RCE-237	36	1.2	1.4	< 0.5		
	211		o-INF-237	58	1.9	137	7.9		
			o-ACE-237	40	0.7	63	2.9	22:1	

P.V.C. header installed in spray aeration column.

Sample Day	Days in Operation	Date	Sample	cis	1.1.1	Tri	Tetra	Ratio Air: Water	Remarks
38	218	05/21/82	INF-238	113	2.9	204	34		
			I-ACE-238	105	1.1	98	15	5:1	
			SACE-238	66	1.9	114	20		
			SACE-HR-238	66	1.0	93	16	597:1	
			SACE-LR-238	68	1.1	99	16	1849:1	
			I-RCE-238	127	1.5	97	14		
	51		II-RCE-238	81	1.3	22	4.8		
	85		III-RCE-238	112	1.4	7.6	1.3		
	51		IV-RCE-238	116	1.6	127	21		
	128		CC1-238	121	1.6	239	24		
	128		CC2-238	124	1.7	244	1.2		
	128		CC3-238	130	2.1	125	N.M.		
	128		CC4-238	146	2.1	13	N.M.		
	51		V-RCE-238	34	1.2	4.8	1.9		
	51		VI-RCE-238	65	1.2	58	9.2		
	67		VII-RCE-238	37	1.2	1.6	< 0.5		
	218		o-INF-238	53	1.5	133	8.2		
			o-ACE-238	55	0.7	61	2.8	21:1	

Air:water ratio in diffused aeration column raised to 8:1.

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/1)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
39	225	05/28/82	INF-239	118	3.1	200	35		
			I-ACE-239	43	0.6	46	5.7	8:1	
			SACE-239	65	1.6	117	22		
			SACE-HR-239	55	1.4	100	17	544:1	
			SACE-LR-239	48	1.4	96	17	1849:1	
			I-RCE-239	139	1.6	118	17		
	58		II-RCE-239	97	1.5	38	7.7		
	92		III-RCE-239	128	1.6	23	9.2		
	58		IV-RCE-239	124	1.6	134	22		
	135		CC1-239	126	1.6	250	20		
	135		CC2-239	127	1.7	253	1.5		
	135		CC3-239	133	1.9	145	N.M.		
	135		CC4-239	143	1.7	26	N.M.		
	58		V-RCE-239	40	1.2	7.7	2.0		
	58		VI-RCE-239	54	1.0	41	5.6		
	74		VII-RCE-239	51	1.3	4.0	29		
	225		o-INF-239	65	1.9	136	8.5		
			o-ACE-239	37	0.6	66	2.5	34:1	
	Resin Column I regenerated with solvent from 6/3/82 to 6/4/82. Resin Columns III-IV, V, VI and VII filled with fresh resin on 6/4/82.								
40	235	06/07/82	INF-240	125	32	212	50		
			I-ACE-240	56	0.6	47	9.0	8:1	
			SACE-HR-240	60	1.6	114	21	544:1	
			SACE-LR-240	44	1.1	86	17	1849:1	
	3		I-RCE-240	1.6	1.0	<0.5	<0.5		
	68		II-RCE-240	108	2.1	57	9.7		
	3		III-RCE-240	N.M.	<0.5	<0.5	<0.5		
	3		IV-RCE-240	0.6	1.1	<0.5	<0.5		
	145		CC1-240	121	1.6	238	21		
	145		CC2-240	123	1.7	245	1.9		
	145		CC3-240	138	2.0	173	<0.5		
	145		CC4-240	151	2.0	61	0.9		
	3		V-RCE-240	<0.5	<0.5	<0.5	<0.5		
	3		VI-RCE-240	<0.5	<0.5	<0.5	<0.5		
	3		VII-RCE-240	<0.5	<0.5	<0.5	<0.5		
	235		o-INF-240	53	1.4	135	8.1		
			o-ACE-240	42	0.6	66	2.5	24:1	
	Air pipe on air lift pump raised to 1 foot. Spray aeration column was drained before each use for all subsequent testing.								
41	243	06/15/82	INF-241	115	33	216	42		
			I-ACE-241	50	0.5	41	5.5	8:1	
			SACE-241	68	1.5	115	20		
			SACE-HR-241	46	0.8	88	17	3704:1	
			SACE-LR-241	42	0.8	77	15	5303:1	
	11		I-RCE-241	7.1	1.5	1.2	2.0		
	76		II-RCE-241	120	2.2	72	12		
	11		III-RCE-241	<0.5	<0.5	<0.5	<0.5		
	11		IV-RCE-241	19	2.3	1.3	1.0		
	153		CC1-241	125	1.6	247	23		
	153		CC2-241	128	1.9	213	2.9		
	153		CC3-241	153	1.8	208	N.M.		
	153		CC4-241	152	2.1	74	N.M.		
	11		V-RCE-241	<0.5	<0.5	<0.5	<0.5		
	11		VI-RCE-241	1.2	<0.5	<0.5	<0.5		
	11		VII-RCE-241	7.8	0.8	<0.7	<0.5		
	243		o-INF-241	61	1.5	148	9.7		
			o-ACE-241	48	0.7	62	2.5	34:1	

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
42	250	06/22/82	INF-242	149	3.5	214	43		
			I-ACE-242	55	0.6	45	6.3	8:1	
			SACE-LR-242	52	0.9	73	12	3704:1	
	18		I-RCE-242	22	1.9	3.5	4.3		
	73		II-RCE-242	132	2.3	79	12		
	18		III-RCE-242	<0.5	<0.5	N.M.	<0.5		
	18		IV-RCE-242	45	1.8	11	4.2		
	160		CC1-242	132	1.9	213	24		
	160		CC2-242	131	1.9	218	3.4		
	160		CC3-242	142	2.0	210	<0.5		
	160		CC4-242	147	2.1	100	N.M.		
	18		V-RCE-242	<0.5	<0.5	<0.5	<0.5		
	18		VI-RCE-242	7.3	<0.5	0.6	0.9		
	18		VII-RCE-242	16	0.9	3.7	1.0		
	250		o-INF-242	74	1.8	131	8.4		
			o-ACE-242	55	0.8	56	2.6	25:1	
43	259	07/01/82	INF-243	134	3.2	198	43		
			I-ACE-243	53	0.6	43	6.3	8:1	
			SACE-LR-243	57	1.0	80	14	3704:1	
	27		I-RCE-243	43	1.8	14	7.8		
	92		II-RCE-243	138	2.4	90	13		
	27		III-RCE-243	< 0.5	1.4	< 0.5	<0.5		
	27		IV-RCE-243	84	2.2	25	2.9		
	169		CC1-243	147	1.8	228	27		
	169		CC2-243	145	1.8	234	4.5		
	169		CC3-243	147	2.1	233	0.5		
	169		CC4-243	155	2.2	116	<0.5		
	27		V-RCE-243	0.8	<0.5	<0.5	<0.5		
	27		VI-RCE-243	7.1	0.6	0.5	<0.5		
	27		VII-RCE-243	15	1.1	2.8	1.3		
	260		o-INF-243	74	1.7	129	8.4		
			o-ACE-243	51	0.7	53	2.7	21:1	

Single-jet spray nozzle installed in spray aeration column.

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
44	266	07/08/82	INF-244	138	3.3	207	41		
			I-ACE-244	56	0.7	46	5.7	8:1	
			SACE-HR-244	53	1.0	90	11	711:1	
			SACE-LR-244	49	1.0	89	11	3704:1	
	34		I-RCE-244	3.3	<0.5	<0.5	<0.5		
	99		II-RCE-244	150	1.7	84	12		
	34		III-RCE-244	1.0	1.7	<0.5	<0.5		
	34		IV-RCE-244	103	2.4	38	4.3		
	176		CC1-244	151	1.9	232	29		
	176		CC2-244	150	2.0	244	7.0		
	176		CC3-244	152	2.1	238	<0.5		
	176		CC4-244	154	2.2	132	N.M.		
	34		V-RCE-244	3.3	<0.5	<0.5	<0.5		
	34		VI-RCE-244	19	0.5	4.9	1.1		
	34		VII-RCE-244	28	<0.5	7.9	1.5		
	266		o-INF-244	80	2.3	139	9.8		
			o-INF-244	46	0.6	56	2.9	20:1	

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
	Air pipe on air lift pump raised to 5 ft.								
45	272	07/14/82	INF-245	138	1.7	197	41		
			I-ACE-245	48	0.7	44	4.3	8:1	
			SACE-HR-245	50	1.0	83	12	616:1	
			SACE-LR-245	49	1.2	91	16	3704:1	
	40		I-RCE-245	7.6	0.8	0.5	< 0.5		
	105		II-RCE-245	151	1.5	92	14		
	40		III-RCE-245	2.5	2.0	< 0.5	< 0.5		
	40		IV-RCE-245	125	2.6	54	5.1		
	182		CC1-245	163	2.2	236	28		
	182		CC2-245	167	2.3	258	4.6		
	182		CC3-245	146	1.9	239	< 0.5		
	182		CC4-245	156	2.2	152	N.M.		
	40		V-RCE-245	7.6	0.8	0.5	< 0.5		
	40		VI-RCE-245	22	0.5	5.6	1.1		
	40		VII-RCE-245	32	0.5	10	1.9		
	272		o-INF-245	63	1.5	99	9.6		
			o-ACE-245	38	0.5	45	2.2	32:1	
	Air:water ratio in diffused aeration column raised to 15:1.								
46	281	07/23/82	INF-246	154	3.5	203	39		
			I-ACE-246	32	0.5	28	2.8	15:1	
			SACE-246	79	2.0	130	21		
			SACE-HR-246	50	1.2	89	14	661:1	
			SACE-LR-246	55	1.3	99	18	3704:1	
			o-INF-246	80	2.1	146	7.9		
			o-ACE-246	39	0.7	46	1.8	24:1	
47	287	07/29/82	INF-247	129	3.4	200	40		
			I-ACE-247	33	< 0.5	29	2.0	15:1	
			SACE-HR-247	54	1.4	84	17	578:1	
			SACE-LR-247	60	1.5	110	20	3704:1	
	55		I-RCE-247	130	1.7	57	14		
	120		II-RCE-247	141	3.1	112	10		
	55		III-RCE-247	15	0.6	< 0.5	< 0.5		
	55		IV-RCE-247	110	1.4	78	10		
	197		CC1-247	145	1.9	219	31		
	197		CC2-247	146	2.0	239	7.5		
	197		CC3-247	149	2.0	247	< 0.5		
	197		CC4-247	161	2.1	188	< 0.5		
	55		V-RCE-247	15	< 0.5	1.3	< 0.5		
	55		VI-RCE-247	27	0.6	7.7	1.1		
	55		VII-RCE-247	30	0.4	11	1.5		
	287		o-INF-247	71	1.8	141	6.4		
			o-INF-247	39	0.7	48	1.4	27:1	
	Resin Column II regenerated from 8/3/82 to 8/4/82.								

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
48	296	08/06/82	INF-248	128	2.8	197	47		
			I-ACE-248	37	0.5	30	1.8	15:1	
			SACE-HR-248	56	1.1	80	16	645:1	
			SACE-LR-248	55	1.1	75	14	3742:1	
			O-INF-248	70	1.8	121	9.4		
			O-ACE-248	37	0.8	42	2.4	26:1	
		Air pipe on airlift pump raised to 10 ft.							
49	302	08/12/82	INF-249	121	2.5	186	33		
			I-ACE-249	32	0.6	27	2.8	15:1	
			SACE-HR-249	55	0.6	83	15	585:1	
			SACE-LR-249	57	1.2	85	17	3742:1	
	69		I-RCE-249	115	1.4	59	11		
	8		II-RCE-249	3.9	0.6	1.1	1.0		
	69		III-RCE-249	32	0.6	< 0.5	< 0.5		
	69		IV-RCE-249	149	1.8	91	14		
	211		CC1-249	128	1.9	220	30		
	211		CC2-249	122	1.8	223	7.6		
	211		CC3-249	154	2.2	235	2.0		
	211		CC4-249	142	2.2	204	0.5		
	69		V-RCE-249	19	0.5	2.4	0.9		
	69		VI-RCE-249	27	0.7	8.5	0.7		
	69		VII-RCE-249	33	<0.5	2.4	0.9		
	302		O-INF-249	64	1.7	111	8.0		
			O-ACE-249	46	1.0	43	2.4	22:1	
50	310	08/20/82	INF-250	114	2.4	192	38		
			I-ACE-250	26	<0.5	18	2.2	15:1	
			SACE-HR-250	55	1.0	80	16	446:1	
			SACE-LR-250	61	1.1	90	18	3742:1	
			O-INF-250	84	2.3	129	9.5		
			O-ACE-250	48	1.0	49	3.3	21:1	
51	317	08/27/82	INF-251	123	2.7	212	36		
			I-ACE-251	47	0.8	37	3.9	15:1	
			SACE-HR-251	57	0.8	83	15	645:1	
			SACE-LR-251	57	1.1	88	17	3742:1	
	84		I-RCE-251	152	1.2	65	11		
	23		II-RCE-251	14	0.9	2.1	2.6		
	84		III-RCE-251	57	2.1	2.0	<0.5		
	84		IV-RCE-251	143	1.6	121	14		
	226		CC1-251	126	1.6	216	30		
	226		CC2-251	127	1.9	235	12		
	226		CC3-251	171	2.4	260	3.8		
	226		CC4-251	;46	2.2	225	0.8		
	84		V-RCE-251	20	0.6	3.4	<0.5		
	84		VI-RCE-251	34	0.8	11	1.2		
	84		VII-RCE-251	35	0.8	15	2.2		
	317		O-INF-251	69	1.9	121	9.3		
			O-ACE-251	42	0.8	38	2.5	30:1	

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
52	321	08/31/82	INF-252	150	2.5	196	33		
			I-ACE-252	32	0.6	30	3.2	15:1	
			SACE-HR-252	59	1.1	84	16	645:1	
			O-INF-252	71	2.2	120	9.2		
			O-ACE-252	38	0.8	39	2.3	24:1	
53	330	09/09/82	INF-253	151	2.6	198	46		
			I-ACE-253	31	0.5	27	4.3	15:1	
			SACE-HR-253	48	1.2	73	10	550:1	
	97		I-RCE-253	142	1.6	71	11		
	36		II-RCE-253	35	1.4	3.8	2.2		
	97		III-RCE-253	95	1.9	3.1	0.5		
	97		IV-RCE-253	145	1.7	118	13		
	239		CC1-253	126	1.7	221	31		
	239		CC2-253	142	2.3	256	23		
	239		CC3-253	159	2.3	246	2.7		
	239		CC4-253	152	2.2	236	2.1		
	97		V-RCE-253	25	0.7	4.4	0.5		
	97		VI-RCE-253	36	1.0	14	1.3		
	97		VII-RCE-253	36	0.6	18	3.0		
	330		O-INF-253	81	1.7	125	8.6		
			O-ACE-253	42	1.2	42	6.8	27:1	
	Two feet of packing material and 5-nozzle header were installed in the spray aeration column.								
54	338	09/17/82	INF-254	108	2.5	183	31		
			I-ACE-254	33	0.7	34	5.8	15:1	
			SACE-HR-254	23	0.6	37	5.9	550:1	
			SACE-25-254 11	21	0.8	36	5.9	748:1	
			SACE-15-254 12	23	0.8	38	6.2	1247:1	
			SACE- 5-254 13	21	0.8	36	6.3	3742:1	
	105		I-RCE-254	150	1.5	84	13		
	44		II-RCE-254	80	1.6	12	4.7		
	105		III-RCE-254	92	1.5	4.8	0.5		
	105		IV-RCE-254	136	1.4	119	19		
	247		CC1-254	150	1.6	222	28		
	247		CC2-254	144	2.7	262	23		
	247		CC3-254	170	2.2	249	3.6		
	247		CC4-254	152	2.1	237	0.5		
	105		V-RCE-254	29	< 0.5	4.3	0.6		
	105		VI-RCE-254	36	< 0.5	12	1.4		
	105		VII-RCE-254	41	0.5	18	2.0		
	338		O-INF-254	75	1.9	115	8.5		
			O-ACE-254	43	0.9	38	2.2	28:1	
55	344	09/23/82	INF-255	138	2.1	180	34		
			I-ACE-255	49	0.7	43	3.9	15:1	
			SACE-HR-255	20	0.7	30	4.3	567:1	
			SACE-25-255	20	0.9	31	5.1	748:1	
			SACE-15-255	19	0.7	30	4.9	1247:1	
			SACE- 5-254	20	0.8	29	5.1	3742:1	
			O-INF-255	79	2.2	120	9.1		
			O-ACE-255	31	0.6	33	1.7	27:1	

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
56	351	09/30/82	INF-256	134	2.8	227	43		
			I-ACE-255	50	0.8	46	4.8	15:1	
			SACE-HR-256	23	0.8	36	5.2	535:1	
			SACE-25-256	23	0.5	35	5.3	748:1	
			SACE-15-256	26	0.6	41	6.6	1247:1	
			SACE- 5-256	23	0.5	35	5.3	3742:1	
	118		I-RCE-256	172	1.3	78	10		
	57		II-RCE-256	120	2.0	16	3.6		
	118		III-RCE-256	107	1.6	7.7	0.6		
	118		IV-RCE-256	137	1.3	114	13		
	260		CC1-256	140	1.6	224	31		
	260		CC2-256	159	2.3	267	20		
	260		CC3-256	146	2.2	282	4.5		
	260		CC4-256	155	2.2	247	1.1		
	118		V-RCE-256	33	0.5	7.5	1.1		
	118		VI-RCE-256	43	0.5	16	1.9		
	118		VII-RCE-256	47	0.6	21	2.3		
	351		O-INF-256	100	2.2	114	8.9		
			O-ACE-256	40	0.6	32	1.7	16:1	
57	359	10/08/82	INF-257	162	2.0	217	34		
			I-ACE-257	48	<0.5	43	3.9		
			SACE-15-257	18	0.7	28	4.1	1247:1	
			O-INF-257	115	2.0	121	6.3		
			O-ACE-257	31	0.5	31	1.6	25:1	
58	366	10/15/82	INF-258	149	2.5	207	32		
			I-ACE-258	56	0.9	57	5.2	15:1	
			SACE-HR-258	23	0.8	35	6.1	623:1	
			SACE-25-258	20	0.8	31	4.0	748:1	
			SACE-15-258	19	0.7	30	4.7	1247:1	
			SACE- 5-258	17	0.6	27	3.9	3742:1	
	133		I-RCE-258	160	1.8	105	16		
	72		II-RCE-258	150	2.4	55	14		
	133		III-RCE-258	148	2.3	11	0.7		
	133		IV-RCE-258	151	1.6	166	17		
	275		CC1-258	172	2.8	267	39		
	275		CC2-258	167	2.9	287	22		
	275		CC3-258	171	3.2	319	7.3		
	275		CC4-258	162	3.2	308	1.8		
	133		V-RCE-258	40	0.8	6.5	1.1		
	133		VI-RCE-258	50	0.8	20	1.7		
	133		VII-RCE-258	53	1.0	31	2.8		
	366		O-INF-258	87	1.7	121	6.4		
			O-ACE-258	41	0.7	36	1.9	25:1	
59	372	10/21/82	INF-259	167	2.1	218	29		
			I-ACE-259	57	0.7	53	3.7	15:1	
			SACE-HR-259	28	0.5	45	5.8	604:1	
			SACE-25-259	28	0.6	42	6.4	748:1	
			SACE-15-259	24	0.6	36	5.0	1247:1	
			SACE- 5-259	21	0.5	33	4.5	3742:1	
			O-INF-259	92	1.7	122	6.2		
			O-ACE-259	41	0.7	32	1.7	25:1	

Resin Column I regenerated from 10/28/82 to 10/29/82.

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
60	383	11/01/82	INF-260	151	2.6	222	32		
			I-ACE-260	57	0.7	53	4.8	15:1	
			SACE-HR-260	25	1.0	33	5.7	584:1	
			SACE-25-260	23	0.9	36	4.7	748:1	
			SACE-15-260	20	1.0	31	5.3	1247:1	
			SACE- 5-260	19	0.8	32	4.7	3742:1	
	3		I-RCE-260	1.5	0.9	1.1	<0.5		
	89		II-RCE-260	181	2.8	92	9.7		
	150		III-RCE-260	166	2.1	23	2.0		
			IV-RCE-260		(being regenerated)				
	292		CC1-260	182	3.2	290	31		
	292		CC2-260	190	3.3	305	31		
	292		CC3-260	186	3.4	327	12		
	292		CC4-260	173	3.3	322	3.2		
	150		V-RCE-260	48	0.9	12	1.3		
	150		VI-RCE-260	56	1.1	25	2.5		
	150		VII-RCE-260	57	1.1	34	3.1		
	383		O-INF-260	88	1.6	118	7.4		
			O-ACE-260	53	0.8	32	1.9	25:1	

Two additional feet of packing material installed in spray aeration column.

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
61	390	11/08/82	INF-261	147	2.9	237	34		
			I-ACE-261	60	<0.5	60	4.2	15:1	
			SACE-HR-261	14	0.6	19	2.5	604:1	
			SACE-25-261	12	0.9	17	3.0	748:1	
			SACE-15-261	11	0.6	16	2.3	1247:1	
			SACE- 5-261	6.4	<0.5	10	1.4	3742:1	
			O-INF-261	109	1.9	121	7.5		
			O-ACE-261	42	0.7	35	1.9	20:1	

Resin Column IV regenerated after superloading from 11/1/82 to 11/2/82.

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Ratio Air: Water	Remarks
62	398	11/16/82	INF-262	158	1.9	247	38		
			I-ACE-262	64	1.0	50	5.0	15:1	
			SACE-45-262[14]	11	<0.5	20	1.8	416:1	
			SACE-32-262[15]	7.1	N.M.	14	1.5	584:1	
			SACE- 8-262[16]	5.2	<0.5	9.3	2.1	2339:1	
	18		I-RCE-262	12	1.2	4.1	4.0		
	104		II-RCE-262	180	2.1	79	6.9		
	165		III-RCE-262	175	1.8	31	2.4		
	14		IV-RCE-262	64	1.1	34	9.2		
	307		CC1-262	181	1.9	276	36		
	307		CC2-262	221	2.9	290	24		
	307		CC3-262	192	3.3	281	14		
	307		CC4-262	194	3.3	292	5.9		
	165		V-RCE-262	49	0.9	10	0.8		
	165		VI-RCE-262	48	0.9	23	1.7		
	165		VII-RCE-262	55	0.8	33	2.6		
	398		O-INF-262	87	1.9	119	5.8		
			O-ACE-262	38	0.5	40	2.0	20:1	
63	405	11/23/82	INF-263	173	2.1	240	32		
			I-ACE-263	70	0.9	57	12	15:1	
			SACE-60-263	19	<0.5	29	4.4	312:1	
			SACE-30-263	7.8	<0.5	14	1.7	623:1	
			SACE-10-263	3.8	<0.5	7.9	1.7	1871:1	
			O-INF-263	90	1.7	121	7.5		
			O-ACE-263	53	0.7	35	1.3	20:1	

TABLE B-1

PHASE III - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra	Patio Air: Water	Remarks
64	413	12/01/82	INF-264	214	2.5	305	45		
			I-ACE-264	53	0.6	45	3.5	15:1	
			SACE-51-264	19	0.7	24	6.4	367:1	
			SACE-31-264	8.2	N.M.	12	1.6	604:1	
			SACE-10-264	3.9	N.M.	7.7	1.1	1871:1	
	33		I-RCE-264	72	2.0	31	13		
	119		II-RCE-264	190	2.0	130	13		
	180		III-RCE-264	180	1.5	45	10		
	29		IV-RCE-264	127	2.6	63	13		
	322		CC1-264	177	3.0	249	34		
	322		CC2-264	201	3.2	266	38		
	322		CC3-264	208	3.4	273	15		
	322		CC4-264	205	3.6	294	8.5		
	180		V-RCE-264	50	<0.5	13	0.9		
	180		VI-RCE-264	55	0.5	29	3.4		
	180		VII-RCE-264	58	0.6	39	2.8		
	413		O-INF-264	123	1.9	123	7.2		
			O-ACE-264	49	0.6	43	2.4	20:1	
65	418	12/06/82	INF-265	203	2.2	296	43		
			I-ACE-265	59	0.7	56	4.8	15:1	
			SACE-59-265	19	<0.5	29	4.4	317:1	
			SACE-30-265	29	<0.5	36	3.7		No induced air
			SACE-30-265	11	<0.5	15	2.0	623:1	
			SACE-10-265	4.6	N.M.	8.2	2.1	1871:1	
			O-INF-265	111	1.5	119	7.7		
			O-ACE-265	61	1.3	33	3.5	25:1	
66	426	12/14/82	INF-266	213	2.6	309	39		
			I-ACE-266	59	0.7	55	4.0	15:1	
			SACE-60-266	75	1.5	86	6.7		No induced air
			SACE-60-266	19	0.6	28	3.5	312:1	
			SACE-30-266	11	N.M.	16	2.3	623:1	
			SACE-10-266	5.6	<0.5	9.8	1.6	1871:1	
	46		I-RCE-266	117	2.3	24	6.4		
	42		IV-RCE-266	195	3.5	94	9.9		
	426		O-INF-266	137	1.7	142	6.7		
			O-ACE-266	66	1.1	64	3.6	9.5:1	0 ft level
67	428	12/16/82	INF-267	216	2.7	301	41		
			I-ACE-267	73	1.0	80	5.4	15:1	
			SACE-44-267	16	<0.5	24	4.4	425:1	
			SACE-30-267	10	<0.5	17	2.7	623:1	
			SACE-10-267	39	<0.5	38	4.5		No induced air
			SACE-10-267	4.9	<0.5	8.8	1.2	1871:1	
	48		I-RCE-267	147	3.0	85	15		
	134		II-RCE-267	206	3.3	189	15		
	195		III-RCE-267	206	3.2	85	5.1		
	44		IV-RCE-267	188	2.8	133	15		
	195		V-RCE-267	60	1.2	21	2.3		
	195		VI-RCE-267	70	1.3	42	3.3		
	195		VII-RCE-267	73	1.3	50	4.3		
	428		O-INF-267	129	1.7	134	6.7		
			O-ACE-267	55	0.7	51	2.7	29:1	

PHASE III REPORT:

APPENDIX C

AERATION TESTING RESULTS

C-1 DIFFUSED AERATION TESTING
C-2 SPRAY AERATION TESTING
C-3 AIR-LIFT PUMP TESTING
C-4 PACKED COLUMN AIR STRIPPING TESTING
C-5 SUSPENDED SOLIDS DATA
C-6 AIR SAMPLING TESTING

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TABLE C-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Diffused Aeration Column Results
(All results in ug/l)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water	Remarks
01	2	10/16/81	INF-201	71	2.3	185	42	5:1	
			ACE-201	19	0.5	67	137	5:1	
02	6	10/20/81	INF-202	78	2.8	197	151		
			ACE-202	27	0.5	32	1.7	5:1	
03	8	10/22/81	INF-203	75	2.8	185	39		
			ACE-203	37	N.M.	36	2.8	5:1	
04	13	10/27/81	INF-204	75	2.7	184	41		
			ACE-204	22	N.M.	40	1.5	5:1	
05	15	10/29/81	INF-205	72	2.8	182	34		
			ACE-205	28	N.M.	35	1.2	5:1	
06	20	11/03/81	INF-206	71	2.6	164	35		
			ACE-206	29	N.M.	36	1.3	5:1	
07	22	11/05/81	INF-207	81	2.9	190	40		
			ACE-207	27	N.M.	34	0.9	5:1	
08	26	11/09/81	INF-208	90	2.9	182	34		
			ACE-208	30	N.M.	33	0.7	5:1	
09	29	11/12/81	INF-209	93	3.0	187	34		
			ACE-209	27	N.M.	35	0.8	5:1	
10	33	11/16/81	INF-210	96	3.1	189	37		
			ACE-210	43	0.9	50	7.8	5:1	
11	35	11/18/81	INF-211	100	3.3	197	40		
			ACE-211	42	0.8	49	4.5	5:1	
12	41	11/24/81	INF-212	99	3.2	194	42		
			ACE-212	38	0.8	67	10	5:1	
13	51	12/04/81	INF-213	93	2.4	175	36		
			ACE-213	53	1.1	62	11	5:1	
14	57	12/10/81	INF-214	101	3.3	104	51		
			ACE-214	55	1.2	62	32	5:1	
15	65	12/18/81	INF-215	105	3.2	187	46		
			ACE-215		(sample not taken)			5:1	
16	71	12/24/81	INF-216	94	2.9	172	44		
			ACE-216		(sample not taken)			5:1	
17	76	12/29/81	INF-217	95	2.9	173	45		
			ACE-217		(sample not taken)				
18	83	1/05/82	INF-218	96	2.8	175	45		
			ACE-218	46	0.9	57	8.8	5:1	
19	89	1/11/82	INF-219	105	2.3	202	50		
			ACE-219	51	0.6	59	9.0	5:1	
20	96	1/18/82	INF-220	97	2.3	188	43		
			ACE-220	59	0.9	72	14	5:1	
21	103	1/25/82	INF-221	100	2.1	186	42		
			ACE-221	62	0.7	77	12	5:1	
22	110	2/01/82	INF-222	101	2.2	191	40		
			ACE-222	59	0.6	75	10	5:1	

TABLE C-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Diffused Aeration Column Results
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water	Remarks
23	117	1/08/81	INF-223	109	2.3	198	46		
			ACE-223	71	1.2	82	13	5:1	
24	125	2/17/82	INF-224	132	2.7	208	44		
			ACE-224	81	1.4	93	13	5:1	
25	131	2/23/82	INF-225	123	2.5	202	40		
			ACE-225	87	1.5	105	15	5:1	
26	139	3/03/82	INF-226	131	2.7	214	45		
			ACE-226	85	1.8	137	20	5:1	
27	144	3/08/82	INF-227	131	2.7	211	44		
			ACE-227	89	1.9	140	21	5:1	
28	155	3/19/82	INF-228	121	2.9	234	48		
			ACE-228	104	2.0	166	28	5:1	
29	159	3/23/82	INF-229	127	2.9	238	56		
			ACE-229	82	0.8	95	11	5:1	
30	165	3/29/82	INF-230	132	3.1	253	51		
			ACE-230	94	1.0	119	15	5:1	
31	172	4/05/82	INF-231	124	2.3	224	49		
			ACE-231	78	1.0	103	15	5:1	
32	179	4/12/82	INF-232	112	2.4	201	38		
			ACE-232	92	1.3	134	18	5:1	
33	187	4/20/82	INF-233	130	2.5	210	50		
			ACE-233	99	2.1	121	21	5:1	
34	193	4/26/82	INF-234	132	2.3	208	42		
			ACE-234	91	1.0	102	14	5:1	
35	200	5/03/82	INF-235	146	2.3	188	37		
			ACE-235	93	0.8	93	12	5:1	
36	207	5/10/82	INF-236	136	2.9	183	37		
			ACE-236	131	2.3	149	26	5:1	
37	211	5/14/82	INF-237	119	3.0	216	38		
			ACE-237	74	0.9	69	8.7	5:1	
			ACE-237	60	0.6	47	6.4	5:1	Sample collected in holding tank
38	218	5/21/82	INF-238	113	2.9	204	34		
			ACE-238	105	1.1	98	15	5:1	
39	225	5/28/82	INF-239	118	3.1	200	35		
			ACE-239	58	1.0	68	7.9	5:1	
			ACE-239	43	0.6	46	5.7	8:1	
40	235	6/07/82	INF-240	125	3.2	212	50		
			ACE-240	56	0.6	47	9.0	8:1	
41	243	6/15/82	INF-241	115	3.3	216	42		
			ACE-241	50	0.5	41	5.5	8:1	
42	250	6/22/82	INF-242	149	3.5	214	43		
			ACE-242	55	0.6	45	6.3	8:1	
43	259	7/01/82	INF-243	134	3.2	198	43		
			ACE-243	53	0.6	43	6.3	8:1	

TABLE C-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Diffused Aeration Column Results
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water	Remarks
44	266	7/08/82	INF-244	138	3.3	207	41		
			ACE-244	56	0.7	46	5.7	8:1	
45	272	7/14/82	INF-245	138	1.7	197	41		
			ACE-245	48	0.7	44	4.3	8:1	
46	281	7/23/82	INF-246	154	3.5	203	39		
			ACE-246	32	0.5	28	2.8	15:1	
			ACE-246	36	0.6	33	3.4	15:1	Sample collected when lid was off
47	287	7/29/82	INF-247	125	3.4	210	40		
			ACE-247	33	0.4	29	2.0	15:1	
48	295	8/06/82	INF-248	132	2.8	200	47		
			ACE-248	37	0.5	30	1.8	15:1	
49	301	8/12/82	INF-249	121	2.5	186	33		
			ACE-249	32	0.6	27	2.8	15:1	
50	309	8/20/82	INF-250	114	2.4	192	38		
			ACE-250	26	0.5	18	2.2	15:1	
51	316	8/27/82	INF-251	123	2.7	212	36		
			ACE-251	47	0.8	37	3.9	15:1	
52	320	8/31/82	INF-252	150	2.5	196	33		
			ACE-252	32	0.6	30	3.2	15:1	
53	329	9/09/82	INF-253	151	2.6	198	46		
			ACE-253	31	0.5	27	4.3	15:1	
54	337	9/17/82	INF-254	108	2.5	183	31		
			ACE-254	33	0.7	34	5.8	15:1	
55	343	9/23/82	INF-255	138	2.1	180	34		
			ACE-255	49	0.7	43	3.9	15:1	
56	350	9/30/82	INF-256	134	2.8	227	43		
			ACE-256	50	0.8	46	4.8	15:1	
57	358	10/08/82	INF-257	162	2.0	217	34		
			ACE-257	48	0.5	43	3.9	15:1	
58	365	10/15/82	INF-258	149	2.5	207	32		
			ACE-258	56	0.9	57	5.2	15:1	
59	371	10/21/82	INF-259	167	2.1	218	29		
			ACE-259	57	0.7	53	3.7	15:1	
60	382	11/01/82	INF-260	151	2.6	222	32		
			ACE-260	57	0.7	53	4.8	15:1	
61	389	11/08/82	INF-261	147	2.9	237	34		
			ACE-261	60	0.5	60	4.2	15:1	
62	397	11/16/82	INF-262	158	1.9	247	38		
			ACE-262	64	1.0	50	5.0	15:1	
			ACE-262	62	1.0	48	4.2	15:1	) Sample collected in
			ACE-262	64	1.0	50	4.5	15:1	)
			ACE-262	64	0.7	49	4.8	15:1	) holding
			ACE-262	62	1.2	54	4.2	15:1	)
			ACE-262	62	1.3	53	5.3	15:1	) tank
			ACE-11/18	77	1.1	73	7.3	15:1	

TABLE C-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Diffused Aeration Column Results
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water	Remarks
63	404	11/23/82	INF-263	173	2.1	240	32		
			ACE-263	70	0.9	57	12	15:1	
64	412	12/01/82	INF-264	214	2.5	305	45		
			ACE-264	53	0.6	45	3.5	15:1	
65	417	12/06/82	INF-265	203	2.2	296	43		
			ACE-265	59	0.7	56	4.8	15:1	
66	425	12/14/82	INF-266	213	2.6	309	39		
			ACE-266	59	0.7	55	4.0	15:1	
67	427	12/16/82	INF-267	216	2.7	299	42		
			ACE-267	73	1.0	80	5.4	15:1	
			ACE-267	69	0.9	65	4.6	15:1	Sample collected in holding tank

TABLE C-2

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Spray Aeration Column Results

Sample Day	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
Distribution header with 5 Spraying System Co. Nozzles (3/4 HH-7) installed in Column							
1	12/29/71	INF-217	95	2.9	173	45	
		SACE-217	29	0.9	53	12	534:1
2	1/05/82	INF-218	96	2.8	175	45	
		SACE-218	30	1.0	55	12	519:1
3	1/11/82	INF-219	105	2.3	202	50	
		SACE-219		(sample not taken)			
4	1/18/82	INF-220	97	2.3	188	43	
		SACE-220		(sample not taken)			
5	1/25/82	INF-221	100	2.1	186	42	
		SACE-221	35	0.7	63	15	534:1
6	2/01/82	INF-222	101	2.2	191	40	
		SACE-222	35	0.5	64	12	519:1
7	2/08/82	INF-223	109	2.3	198	46	
		SACE-223	35	1.3	59	12	456:1
8	2/17/82	INF-224	132	2.7	208	44	
		SACE-224	39	1.3	64	12	492:1
9	2/23/82	INF-225	123	2.5	202	40	
		SACE-225	40	1.4	65	20	550:1
10	3/03/82	INF-226	131	2.7	214	45	
		SACE-226	39	1.4	65	13	567:1
11	3/08/82	INF-227	131	2.7	211	44	
		SACE-227	40	1.4	65	13	550:1
12	3/19/82	INF-228	121	2.9	234	48	
		SACE-228	43	1.4	67	14	550:1
13	3/19/82	INF-229	127	2.9	238	56	
		SACE-229	37	0.5	65	12	550:1
14	3/29/82	INF-230	132	3.1	253	51	
		SACE-230	37	0.6	68	12	693:1
15	4/05/82	INF-231	124	2.3	224	49	
		SACE-231	41	0.8	76	14	779:1
16	4/12/82	INF-232	112	2.4	201	38	
		SACE-232	41	0.6	74	14	935:1
17	4/20/82	INF-233	130	2.5	210	50	
		SACE-233	39	0.6	70	13	935:1
18	4/26/82	INF-234	132	2.3	208	42	
		SACE-234	41	0.6	72	21	935:1
19	5/03/82	INF-235	146	2.3	188	37	
		SACE-235	43	0.6	72	14	850:1
20	5/10/82	INF-236	136	2.9	183	37	
		SACE-236	47	0.7	64	13	645:1
21	5/14/82	INF-237	119	3.0	216	38	
		SACE-237	45	1.2	81	13	natural draft
		SACE-237HR	46	0.7	64	13	645:1
		SACE-237LR	45	0.9	79	17	1870:1

NOTES:
SACE - Sample collected with fan off at high water flow rate.
SACE-HR - Sample collected with fan on at high water flow rate.
SACE-LR - Sample collected with fan on at low water flow rate.

TABLE C-2

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Spray Aeration Column Results
(All results in mg/l)
(Cont'd)

Sample Day	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
Pre-spray header installed in Column							
22	5/21/82	INF-239	113	2.9	204	34	
		SACE-238	66	1.9	114	20	natural draft
		SACE-238HR	66	1.0	93	16	603:1
		SACE-238LR	68	1.1	99	16	1,870:1
23	5/28/82	INF-239	118	3.1	200	35	
		SACE-239	65	1.6	117	22	natural draft
		SACE-239HR	55	1.4	100	17	550:1
		SACE-239LR	48	1.4	96	17	1,870:1
24	6/07/82	INF-240	125	3.2	212	50	
		SACE-240HR	60	1.6	114	21	550:1
		SACE-240LR	44	1.1	86	17	1,870:1
		INF-6/9	137	3.3	238	43	
		SACE-6/9	30	0.7	62	11	12,065:1
		INF-6/10	135	3.3	240	48	
		SACE-6/10	65	1.4	123	24	935:1
For all subsequent analyses using the spray aeration column, the column was drained before operation at each air:water ratio tested.							
25	6/15/82	INF-241	115	3.3	216	42	
		SACE-241	68	1.5	115	20	natural draft
		SACE-241HR	46	0.8	88	17	3,740:1
		SACE-241LR	42	0.8	77	15	5,343:1
26	6/22/82	INF-242	149	3.5	214	43	
		SACE-242	77	1.5	108	18	natural draft
		SACE-242LR	52	0.9	73	12	3,740:1
27	7/01/82	INF-243	134	3.2	198	43	
		SACE-243	75	1.3	102	17	natural draft
		SACE-243LR	57	1.0	80	14	3,740:1
Sprayer with 1 Spraying Systems Co. Nozzle (2HH-30500) installed in Column.							
28	7/08/82	INF-244	138	3.3	207	41	
		SACE-244-HR	53	1.0	90	11	719:1
		SACE-244-LR	49	1.0	89	11	3,740:1
29	7/14/82	INF-245	138	1.7	197	41	
		SACE-245-HR	50	1.0	83	12	623:1
		SACE-245LR	49	1.2	91	16	3,740:1
30	7/23/82	INF-246	154	3.5	203	39	
		SACE-246	79	2.0	130	21	natural draft
		SACE-246-HR	50	1.2	89	14	668:1
		SACE-246-LR	55	1.3	99	18	3,740:1
31	7/29/82	INF-247	125	3.4	210	40	
		SACE-247-HR	54	1.4	84	17	584:1
		SACE-247-LR	60	1.5	110	20	3,740:1
32	8/06/82	INF-248	128	2.8	197	47	
		SACE-248-HR	56	1.1	80	16	645:1
		SACE-248-LR	55	1.2	75	14	3,740:1
33	8/12/82	INF-249	121	2.5	186	33	
		SACE-249-HR	55	0.6	83	15	584:1
		SACE-249-LR	57	1.2	85	17	3,740:1

NOTES: SACE - Sample collected with fan off at high water flow rate.
SACE-HR - Sample collected with fan on at high water flow rate.
SACE-LR - Sample collected with fan on at low water flow rate.

TABLE C-2

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Spray Aeration Column Results
(All results in mg/l)
(Cont'd)

Sample Day	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
34	8/20/82	INF-250	114	2.4	192	38	
		SACE-250-HR	55	1.0	80	16	445:1
		SACE-250-LR	61	1.1	90	18	3,740:1
35	8/27/82	INF-251	123	2.7	212	36	
		SACE-251-HR	57	0.8	83	15	645:1
		SACE-251-LR	57	1.1	88	17	3,740:1
36	8/31/82	INF-252	150	2.5	196	33	
		SACE-252-HR	59	1.1	84	16	645:1
37	9/09/82	INF-253	151	2.6	198	46	
		SACE-253-HR	48	1.2	73	10	550:1

Two feet of Munters packing added on 9/16/82

Sample Day	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
38	9/17/82	INF-254	108	2.5	183	31	
		SACE-254-34gpm	23	0.6	37	5.9	550:1
		SACE-254-25gpm	21	0.8	36	5.9	748:1
		SACE-254-15gpm	23	0.8	38	6.2	1,247:1
		SACE-254-5gpm	21	0.8	36	6.3	3,740:1
39	9/23/82	INF-255	138	2.1	180	34	
		SACE-255-33gpm	20	0.7	30	4.3	567:1
		SACE-255-25gpm	20	0.9	31	5.1	748:1
		SACE-255-15gpm	19	0.7	30	4.9	1,247:1
		SACE-255-5gpm	20	0.8	29 29	5.1	3,740:1
40	9/30/82	INF-256	134	2.8	227	43	
		SACE-256-35gpm	23	0.8	36	5.2	534:1
		SACE-256-25gpm	23	0.5	35	5.3	748:1
		SACE-256-15gpm	26	0.6	41	6.6	1,247:1
		SACE-256-5gpm	23	0.5	35	5.3	3,740:1
41	10/08/82	INF-257	162	2.0	217	34	
		SACE-257	18	0.7	28	4.1	1,247:1
42	10/15/82	INF-258	INF-258	149	2.5	207	32
		SACE-258-30gpm	23	0.8	35	6.1	623:1
		SACE-258-25gpm	20	0.8	31	4.0	748:1
		SACE-258-15gpm	19	0.7	30	4.7	1,247:1
		SACE-258-5gpm	17	0.6	27	3.9	3,740:1
43	10/21/82	INF-259	167	2.1	218	29	
		SACE-259-31gpm	28	0.5	45	5.8	603:1
		SACE-259-25gpm	28	0.6	42	6.4	748:1
		SACE-259-15gpm	24	0.6	36	5.0	1,247:1
		SACE-259-5gpm	21	0.5	33	4.5	3,740:1
44	11/01/82	INF-260	151	2.6	222	32	
		SACE-260-32gpm	25	1.0	33	5.7	584:1
		SACE-260-25gpm	23	0.9	36	4.7	748:1
		SACE-260-15gpm	20	1.0	31	5.3	1,247:1
		SACE-260-5gpm	19	0.8	32	4.7	3,740:1

Two additional feet of Munters Packing added (Total: 4 feet of packing)

Sample Day	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
45	11/08/82	INF-261	147	2.9	237	34	
		SACE-261-31gpm	13	0.6	19	2.5	603:1
		SACE-261-25gpm	12	0.9	17	3.0	748:1
		SACE-261-15gpm	11	0.6	16	2.3	1,247:1
		SACE-261-5gpm	6.4	1 0.5	10	1.4	3,740:1

NOTES: SACE - Sample collected with fan off at high water flow rate.
SACE-HR - Sample collected with fan on at high water flow rate.
SACE-LR - Sample collected with fan on at low water flow rate.

TABLE C-2

GLEN COVE, N.Y., PILOT PLANT
PHASE III
Spray Aeration Column Results
(All results in mg/l)
(Cont'd)

Sample Day	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
46	11/16/82	INF-262	158	1.9	247	38	
		SACE-262-45gpm	11	0.5	20	1.8	416:1
		SACE-262-32gpm	7.1	N.M.	14	1.5	584:1
		SACE-262-8 gpm	5.2	0.5	9.3	2.1	2,338:1
47	11/23/82	INF-263	173	2.1	240	32	
		SACE-263-60gpm	19	9.5	29	4.4	312:1
		SACE-263-30gpm	7.8	0.5	14	1.7	623:1
		SACE-263-10gpm	3.8	0.5	7.9	8.1	1,870:1
48	12/01/82	INF-264	214	2.5	305	45	
		SACE-264-51gpm	19	0.7	24	6.4	367:1
		SACE-264-31gpm	8.3	N.M.	12	1.6	603;1
		SACE-264-10gpm	3.9	N.M.	7.7	1.1	1,870:1
49	12/06/82	INF-265	203	2.2	296	43	
		SACE-265-59gpm	19	0.5	29	4.4	317:1
		SACE-265-30gpm	29	0.5	36	3.7	natural draft
		SACE-265-30gpm	11	0.5	15	2.0	623:1
		SACE-265-10gpm	4.6	N.M.	8.2	2.1	1,870:1
50	12/14/82	INF-266	213	2.6	309	39	
		SACE-266-60gpm	75	1.5	86	6.7	natural draft
		SACE-266-60gpm	19	0.6	86	3.5	312:1
		SACE-266-30gpm	11	N.M.	16	2.3	623:1
		SACE-266-10gpm	5.6	0.5	9.8	1.6	1,870:1
51	12/16/82	INF-267	216	2.7	301	41	
		SACE-267-44gpm	16	0.5	24	4.4	425:1
		SACE-267-30gpm	10	0.5	17	2.7	623:1
		SACE-267-10gpm	39	0.5	38	4.5	natural draft
		SACE-267-10gpm	4.9	0.5	8.8	1.2	1,870:1

TABLE C-3

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIRLIFT PUMP RESULTS

(All results in ug/l)

Sample Day	Date	Sample	cis	1,1,1	Tri	Tetra	Water: Air Water	Remarks
01	10/20/81	0-INF-202	28	N.M.	80	8.2		
		0-ACE-202	23	0.8	58	2.3	15:1	
02	10/22/81	0-INF-203	31	0.9	103	5.8		
		0-ACE-203	28	N.M.	66	2.3	19:1	
03	10/27/81	0-INF-204		(Sample not taken)				
		0-ACE-204	25	N.M.	62	2.1	20:1	
04	10/29/81	0-INF-205		(Sample not taken)				
		0-ACE-205	24	N.M.	59	2.2	17:1	
05	11/03/81	0-INF-206	28	1.7	135	9.3		
		0-ACE-206	28	N.M.	65	1.7		Manometer not working
06	11/05/81	0-INF-207	33	1.9	142	12		
		0-ACE-207	26	N.M.	67	2.0	22:1	
07	11/09/81	0-INF-208	37	2.6	149	11		
		0-ACE-208	25	N.M.	65	1.1	18:1	
08	11/12/81	0-INF-209	41	2.9	160	11		
		0-ACE-209	18	0.6	46	2.3	16:1	
09	11/16/81	0-INF-210	41	2.8	163	11		
		0-ACE-210	24	0.7	62	3.1	17:1	
10	11/18/81	0-INF-211	40	2.7	161	11		
		0-ACE-211	23	0.8	60	3.1	16:1	
11	11/24/81	0-INF-212	41	2.8	158	31		
		0-ACE-212	26	1.3	65	3.6	15:1	
12	12/04/81	0-INF-213	42	2.9	161	18		) Weir not operating properly
		0-ACE-213	27	1.3	74	43		
		*0-ACE-213	26	1.4	74	41		
Air lift pump not operated or sampled from December 4, 1981 to January 18, 1982 due to out of service air blower.								
13	1/18/82	0-INF-220		(Sample not taken)				
		0-ACE-220	29	0.9	69	4.3		) Air measuring mano) meter not operatin
		*0-ACE-220	31	0.7	69	4.6		
14	1/25/82	0-INF-221	40	1.2	151	12		
		0-ACE-221	27	0.6	66	3.3		) Air measuring mano) meter not operatin
		*0-ACE-221	25	0.5	61	3.2		
15	2/01/82	0-INF-222	36	1.4	133	8.4		
		0-ACE-222	19	0.5	56	3.0		) Air measuring mano) meter not operatin
		*0-ACE-222	24	0.5	60	3.0		
16	2/08/82	0-INF-223		(Sample not taken)				
		0-ACE-223	28	0.6	67	3.1		) Air measuring mano) meter not operati
		*0-ACE-223	27	0.6	63	2.9		
17	2/17/82	0-INF-224	46	1.4	150	11		
		0-ACE-224	31	0.7	66	3.0		Air measuring mano meter not operati

* Sample collected between baffle and weir.

TABLE C-3

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIRLIFT PUMP RESULTS
(Continued)
(All results in ug/l)

Sample Day	Date	Sample	cis	1,1,1	Tri	Tetra	Water: Air Water	Remarks
18	2/23/82	0-INF-225	50	1.6	136	8.3		
		0-ACE-225	40	0.9	68	3.0		Air measuring manometer not operating
19	3/03/82	0-INF-226	50	1.6	136	8.6		
		0-ACE-226	40	0.9	68	3.1		Air measuring manometer not operating
20	3/08/82	0-INF-227	55	2.0	149	9.8		
		0-ACE-227	39	0.9	70	3.2	16:1	
21	3/19/82	0-INF-228		(Sample not taken)				
		0-ACE-228	49	1.0	73	3.5	17:1	
22	3/23/82	0-INF-229	47	1.0	137	7.8		
		0-ACE-229	43	0.9	70	3.4	17:1	
23	3/29/82	0-INF-230	57	1.2	148	8.6		
		0-ACE-230	44	0.6	73	3.7	40:1	
24	4/05/82	0-INF-231	72	1.4	140	10		
		0-ACE-231	40	0.5	65	2.7	19:1	
25	4/12/82	0-INF-232	67	1.3	142	8.6		
		0-ACE-232	39	0.5	69	3.1	19:1	
26	4/20/82	0-INF-233	59	1.1	141	8.9		
		0-ACE-233	47	0.6	71	3.5	23:1	
27	4/26/82	0-INF-234	69	1.3	145	9.9		
		0-ACE-234	44	0.6	71	3.4	27:1	
28	5/03/82	0-INF-235	73	1.3	137	9.9		
		0-ACE-235	54	0.6	71	3.0	50:1	
29	5/10/82	0-INF-236	68	2.1	139	8.3		
		0-ACE-236	54	0.7	65	3.0	51:1	
30	5/14/82	0-INF-237	58	1.9	137	7.9		
		0-ACE-237	40	0.7	63	2.9	22:1	
		0-ACE-237	41	0.5	65	3.1	22:1	Sample taken after weir
31	5/21/82	0-INF-238	53	1.5	133	8.2		
		0-ACE-238	55	0.7	61	2.8	21:1	
32	5/28/82	0-INF-239	65	1.9	136	8.5		
		0-ACE-239	37	0.6	66	2.5	34:1	
33	6/07/82	0-INF-240	53	1.4	135	8.1		
		0-ACE-240	42	0.6	66	2.5	24:1	
34	6/15/82	0-INF-241	61	1.5	148	9.7		
		0-ACE-241	48	0.7	62	2.5	34:1	Pipe raised to 1 ft above pump head
35	6/22/82	0-INF-242	74	1.8	131	8.4		
		0-ACE-242	55	0.8	56	2.6	25:1	
36	7/01/82	0-INF-243	74	1.7	129	8.4		
		0-ACE-243	51	0.7	53	2.7	21:1	
37	7/08/82	0-INF-244	80	2.3	139	9.8		
		0-ACE-244	46	0.6	56	2.9	20:1	

TABLE C-3

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIRLIFT PUMP RESULTS
(Continued)
(All results in ug/l)

Sample Day	Date	Sample	cis	1,1,1	Tri	Tetra	Water: Air Water	Remarks
37	7/08/82	0-INF-244	80	2.3	139	9.8		
		0-ACE-244	46	0.6	56	2.9	20:1	
38	7/14/82	0-INF-245	63	1.5	99	9.6		
		0-ACE-245	49	0.6	51	3.3	20:1	
		0-ACE-245	38	0.5	45	2.2	32:1	Pipe raised to 5 ft above pump head
39	7/23/82	0-INF-246	80	2.1	146	7.9		
		0-ACE-246	39	0.7	46	1.8	24:1	
40	7/29/82	0-INF-247	71	1.8	141	6.4		
		0-ACE-247	39	0.7	48	1.4	27:1	
41	8/06/82	0-INF-248	70	1.8	121	9.4		
		0-ACE-248	37	0.8	42	2.4	26:1	
42	8/12/82	0-INF-249	64	1.7	111	8.0		
		0-ACE-249	46	1.0	43	2.4	22:1	Pipe raised to 10 f above pump head
43	8/20/82	0-INF-250	84	2.3	129	9.5		
		0-ACE-250	48	1.0	49	3.3	21:1	
44	8/27/82	0-INF-251	69	1.9	121	9.3		
		0-ACE-251	42	0.8	38	2.5	30:1	
45	8/31/82	0-INF-252	71	2.2	120	9.2		
		0-ACE-252	38	0.8	39	2.3	24:1	
46	9/09/82	0-INF-253	81	1.7	125	8.6		
		0-ACE-253	40	1.3	39	2.0	27:1	
47	9/17/82	0-INF-254	75	1.9	115	8.5		
		0-ACE-254	43	0.9	38	2.2	28:1	
48	9/23/82	0-INF-255	79	2.2	120	9.1		
		0-ACE-255	31	0.6	33	1.7	27:1	
49	9/30/82	0-INF-256	100	2.2	114	8.9		
		0-ACE-256	40	0.6	32	1.7	16:1	
50	10/08/82	0-INF-257	115	20	121	6.3		
		0-ACE-257	31	0.5	31	1.6	25:1	
51	10/15/82	0-INF-258	87	1.7	121	6.4		
		0-ACE-258	41	0.7	36	1.9	25:1	
52	10/21/82	0-INF-259	92	1.7	122	6.2		
		0-ACE-259	41	0.7	32	1.7	25:1	
53	11/01/82	0-INF-260	88	1.6	118	7.4		
		0-ACE-260	53	0.8	32	1.9	25:1	
54	11/08/82	0-INF-261	109	1.9	121	7.5		
		0-ACE-261	42	0.7	35	1.9	20:1	
55	11/16/82	0-INF-262	87	1.9	119	5.8		
		0-ACE-262	38	0.5	40	2.0	20:1	
56	11/23/82	0-INF-263	90	1.7	121	7.5		
		0-ACE-263	53	0.7	35	1.3	20:1	
57	12/01/82	0-INF-264	123	1.9	123	7.2		
		0-ACE-264	49	0.6	43	2.4	20:1	

TABLE C-3

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIRLIFT PUMP RESULTS
(Continued)
(All results in ug/l)

Sample Day	Date	Sample	cis	1,1,1	Tri	Tetra	Water: Air Water	Remarks
58	12/06/82	0-INF-265	111	1.5	119	7.7		
								Pipe raised (ft abov pump head)
		0-ACE-50 cfm	76	1.7	55	6.2	83:1	0
		0-ACE-50 cfm	76	1.6	52	6.3	22:1	5
		0-ACE-50 cfm	70	1.4	41	4.6	22:1	10
		0-ACE-65 cfm	71	1.3	48	5.3	11:1	0
		0-ACE-72 cfm	69	1.3	41	4.9	15:1	5
		0-ACE-72 cfm	79	1.3	37	4.2	22:1	10
		0-ACE-85 cfm	67	1.4	40	4.6	17:1	5
		0-ACE-100 cfm	61	1.3	33	3.5	25:1	10
59	12/14/82	0-INF-266	137	1.7	142	6.7		
		0-ACE-266	66	1.1	64	3.6	45:1	0
60	12/16/82	0-INF-267	129	1.7	134	6.7		
		0-ACE-65 cfm	78	1.2	59	3.4	11:1	0
		0-ACE-65 cfm	59	0.9	58	3.1	16:1	5
		0-ACE-65 cfm	55	0.7	51	2.7	29:1	10

C-4 U.S. EPA PACKED COLUMN AIR STRIPPER

Notes

a	Average for sampling day
b	Average for both sampling days
c	Natural Draft for 1" (2.5 cm) plastic saddles at flow rate of 84.8 gpm (321.0 lpm)
d	Natural Draft for 2" (5.0 cm) plastic saddles at flow rate of 38.5 gpm (145.7 lpm)

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

A. Using 1" (2.5 cm) Plastic Saddles As Packing

Air to Water Ratio	Sample Port Location	Date of Testing	Concentrations		Percent Removal	
			Actual	Average	Actual	Average
1) Cis-1,2-dichloroethylene						
	Influent	8/20/82	178			
		8/20/82	161	169.5[a]		
		12/14/82	214			
		12/14/82	214	214.0[a]		
				191.8[b]		
85:1	0.5 ft	8/20/82	85		49.9	
	9.5 ft	8/20/82	25		85.2	
	18.0 ft	8/20/82	< 0.5		> 99.7	
	Effluent	8/20/82	< 0.5		> 99.7	
45:1	0.5 ft	8/20/82	101		40.4	
		12/14/82	131	116	38.8	39.5
	9.5 ft	8/20/82	29		82.9	
	13.5 ft	12/14/82	6.8		96.8	
	18.0 ft	8/20/82	0.9		99.5	
	Effluent	8/20/82	0.8		99.5	
		12/14/82	0.5	0.65	99.8	99.7
25:1	0.5 ft	8/20/82	121		28.6	
		12/14/82	193	157	9.8	18.1
	9.5 ft	8/20/82	57		66.4	
	13.5 ft	12/14/82	35		83.6	
	18.0 ft	8/20/82	8.4		95.0	
	Effluent	8/20/82	9.8		94.2	
		12/14/82	8.4	9.1	96.1	95.3
15:1	0.5 ft	8/20/82	115		32.1	
		12/14/82	184	149.5	14.2	22.1
	9.5 ft	8/20/82	78		54.0	
	13.5 ft	12/14/82	88		58.9	
	18.0 ft	8/20/82	20		88.2	
	Effluent	8/20/82	19		88.8	
		12/14/82	30	24.5	86.0	87.2

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TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

A. Using 1" (2.5 cm) Plastic Saddles As Packing (Continued)

Air to Water Ratio	Sample Port Location	Date of Testing	Concentrations		Percent Removal	
			Actual	Average	Actual	Average
10:1	0.5 ft	8/20/82	111		34.5	
	9.5 ft	8/20/82	89		47.5	
	18.0 ft	8/20/82	45		73.5	
	Effluent	8/20/82	49		71.1	
8:1	0.5 ft	12/14/82	197		7.9	
	13.5 ft	12/14/82	166		22.4	
	Effluent	12/14/82	80		62.6	
5:1	0.5 ft	8/20/82	122		28.0	
	9.5 ft	8/20/82	101		40.4	
	18.0 ft	8/20/82	65		61.7	
	Effluent	8/20/82	79		53.4	
Natural Draft[c]	0.5 ft	12/14/82	159		25.7	
	13.5 ft	12/14/82	172		19.3	
	Effluent	12/14/82	144		32.7	
2) Trichloroethylene						
	Influent	8/20/82	223			
		8/20/82	257	240[a]		
		12/14/82	347			
		12/14/82	344	345.5[a]		
				292.75[b]		
85:1	0.5 ft	8/20/82	165		31.3	
	9.5 ft	8/20/82	29		87.9	
	18.0 ft	8/20/82	<0.5		> 99.8	
	Effluent	8/20/82	<0.5		> 99.8	
45:1	0.5 ft	8/20/82	207		13.8	
		12/14/82	173	190	49.9	35.1
	9.5 ft	8/20/82	32		86.7	
	13.5 ft	12/14/82	5.4		98.4	
	18.0 ft	8/20/82	0.6		99.7	
	Effluent	8/20/82	0.7		99.7	
		12/14/82	<0.5	< 0.6	> 99.8	> 99.8

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

A. Using 1" (2.5 cm) Plastic Saddles As Packing (Continued)

Air to Water Ratio	Sample Port Location	Date of Testing	Concentrations		Percent Removal	
			Actual	Average	Actual	Average
25:1	0.5 ft	8/20/82	186		22.5	
		12/14/82	301	243.5	12.9	16.8
	9.5 ft	8/20/82	50		79.2	
	13.5 ft	12/14/82	24		93.1	
	18.0 ft	8/20/82	3.3		98.6	
	Effluent	8/20/82	4.1		98.3	
		12/14/82	3.8	3.95	98.9	98.6
15:1	0.5 ft	8/20/82	180		25.0	
		12/14/82	275	227.5	20.4	22.3
	9.5 ft	8/20/82	70		70.8	
	13.5 ft	12/14/82	57		83.5	
	18.0 ft	8/20/82	9.3		96.1	
	Effluent	8/20/82	7.7		96.8	
		12/14/82	13.0	10.35	96.2	96.5
10:1	0.5 ft	8/20/82	168		30.0	
	9.5 ft	8/20/82	89		62.9	
	18.0 ft	8/20/82	26		89.2	
	Effluent	8/20/82	31		87.1	
8:1	0.5 ft	12/14/82	300		13.2	
	13.5 ft	12/14/82	155		55.1	
	Effluent	12/14/82	53		84.6	
5:1	0.5 ft	8/20/82	196		18.3	
	9.5 ft	8/20/82	140		41.7	
	18.0 ft	8/20/82	61		74.6	
	Effluent	8/20/82	77		67.9	
Natural Draft^c	0.5 ft	12/14/82	282		18.4	
	13.5 ft	12/14/82	244		29.4	
	Effluent	12/14/82	195		43.6	

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

A. Using 1" (2.5 cm) Plastic Saddles As Packing (Continued)

Air to Water Ratio	Sample Port Location	Date of Testing	Concentrations		Percent Removal	
			Actual	Average	Actual	Average
3. Tetrachloroethylene						
	Influent	8/20/82	76			
		8/20/82	38	57[a]		
		12/14/82	42			
		12/14/82	39	40.5[a] 48.75[b]		
85:1	0.5 ft	8/20/82	45		21.1	
	9.5 ft	8/20/82	8.2		85.6	
	18.0 ft	8/20/82	< 0.5		> 99.1	
	Effluent	8/20/82	< 0.5		> 99.1	
45:1	0.5 ft	8/20/82	31		45.6	
		12/14/82	18	24.5	55.6	49.7
	9.5 ft	8/20/82	7.6		86.7	
	13.5 ft	12/14/82	< 0.5		> 98.8	
	18.0 ft	8/20/82	< 0.5		> 99.1	
	Effluent	8/20/82	< 0.5		> 99.1	
		12/14/82	< 0.5	< 0.5	> 98.8	> 99.0
25:1	0.5 ft	8/20/82	47		17.5	
		12/14/82	31	39	23.5	20.0
	9.5 ft	8/20/82	11		80.7	
	13.5 ft	12/14/82	1.1		97.3	
	18.0 ft	8/20/82	0.6		98.9	
	Effluent	8/20/82	0.7		98.8	
		12/14/82	< 0.5	< 0.6	> 98.8	> 98.8
15:1	0.5 ft	8/20/82	27		52.6	
		12/14/82	31	29	23.5	
	9.5 ft	8/20/82	8.6		84.9	
	13.5 ft	12/14/82	3.1		92.3	
	18.0 ft	8/20/82	0.7		98.8	
	Effluent	8/20/82	1.0		98.2	
		12/14/82	0.6	0.8	98.5	98.3

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

A. Using 1" (2.5 cm) Plastic Saddles As Packing (Continued)

Air to Water Ratio	Sample Port Location	Date of Testing	Concentrations		Percent Removal	
			Actual	Average	Actual	Average
10:1	0.5 ft	8/20/82	24		57.9	
	9.5 ft	8/20/82	10		82.5	
	18.0 ft	8/20/82	2.3		95.9	
	Effluent	8/20/82	2.7		95.3	
8:1	0.5 ft	12/14/82	35		13.6	
	13.5 ft	12/14/82	8.6		78.8	
	Effluent	12/14/82	3.5		91.3	
5:1	0.5 ft	8/20/82	34		40.3	
	9.5 ft	8/20/82	16		71.9	
	18.0 ft	8/20/82	6.4		88.8	
	Effluent	8/20/82	8.6		84.9	
Natural Draft[c]	0.5 ft	12/14/82	31		23.5	
	13.5 ft	12/14/82	29		28.4	
	Effluent	12/14/82	16		60.5	
4. 1,1,1-trichloroethane						
	Influent	8/20/82	4.8			
		8/20/82	2.7	3.75[a]		
		12/14/82	3.1			
		12/14/82	2.9	3.00[a] 3.38[b]		
85:1	0.5 ft	8/20/82	2.7	28.0		
	9.5 ft	8/20/82	0.5	86.7		
	18.0 ft	8/20/82	< 0.5	> 86.7		
	Effluent	8/20/82	< 0.5	> 86.7		

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

A. Using 1" (2.5 cm) Plastic Saddles As Packing (Continued)

Air to Water Ratio	Sample Port Location	Date of Testing	Concentrations		Percent Removal	
			Actual	Average	Actual	Average
45:1	0.5 ft	8/20/82	2.7		28.0	
		12/14/82	1.8	2.25	40.0	33.4
	9.5 ft	8/20/82	0.6		84.0	
	13.5 ft	12/14/82	< 0.5		> 83.3	
	18.0 ft	8/20/82	< 0.5		> 86.7	
	Effluent	8/20/82	< 0.5		> 86.7	
		12/14/82	< 0.5	< 0.5	> 83.3	> 85.2
25:1	0.5 ft	8/20/82	2.6		30.7	
		12/14/82	3.5	3.05	-	9.8
	9.5 ft	8/20/82	0.7		81.3	
	13.5 ft	12/14/82	< 0.5		> 83.3	
	18.0 ft	8/20/82	1.1		70.7	
	Effluent	8/20/82	1.4		62.7	
		12/14/82	< 0.5	< 0.95	> 83.3	> 71.9
15:1	0.5 ft	8/20/82	2.2		41.3	
		12/14/82	3.0	2.6	0	23.1
	9.5 ft	8/20/82	1.1		70.7	
	13.5 ft	12/14/82	1.2		60.0	
	18.0 ft	8/20/82	1.1		70.7	
	Effluent	8/20/82	0.7		81.3	
		12/14/82	< 0.5	< 0.6	> 83.3	> 82.2
10:1	0.5 ft	8/20/82	2.3		38.7	
	9.5 ft	8/20/82	1.2		68.0	
	18.0 ft	8/20/82	0.5		86.7	
	Effluent	8/20/82	0.5		86.7	
8:1	0.5 ft	12/14/82	3.4		-	
	13.5 ft	12/14/82	2.0		33.3	
	Effluent	12/14/82	1.2		60.0	

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

A. Using 1" (2.5 cm) Plastic Saddles As Packing (Continued)

Air to Water Ratio	Sample Port Location	Date of Testing	Concentrations		Percent Removal	
			Actual	Average	Actual	Average
5:1	0.5 ft	8/20/82	2.9		22.7	
	9.5 ft	8/20/82	1.8		52.0	
	18.0 ft	8/20/82	0.8		78.7	
	Effluent	8/20/82	1.0		73.3	
Natural Draft[c]	0.5 ft	12/14/82	2.5		16.7	
	13.5 ft	12/14/82	2.5		16.7	
	Effluent	12/14/82	2.0		33.3	

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

B. Using 2" (5.0 cm) Plastic Saddles As Packing - Testing Date: 12/14/82

Air to Water Ratio	Sample Port Location	Concentrations	Percent Removal
1. Cis-1,2-dichloroethylene			
	Influent	193	
		201	
		218	
		Average: 204	
45:1	0.5 ft	167	18.1
	Effluent	3.1	98.5
25:1	0.5 ft	186	8.8
	Effluent	11	94.6
15:1	0.5 ft	195	4.4
	Effluent	39	80.9
8:1	0.5 ft	196	3.9
	Effluent	75	63.2
5:1	0.5 ft	192	5.9
	Effluent	116	43.1
Natural Draft[a]	0.5 ft	165	19.1
	Effluent	82	59.8
2. Trichloroethylene			
	Influent	330	
		344	
		345	
		Average: 340	
45:1	0.5 ft	278	18.2
	Effluent	3.7	98.9

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

B. Using 2" (5.0 cm) Plastic Saddles As Packing - Testing Date: 12/14/82 (Continued)

Air to Water Ratio	Sample Port Location	Concentrations	Percent Removal
25:1	0.5 ft	307	9.7
	Effluent	10	97.1
15:1	0.5 ft	291	14.4
	Effluent	22	93.5
8:1	0.5 ft	286	15.9
	Effluent	55	83.8
5:1	0.5 ft	284	16.5
	Effluent	100	70.6
Natural Draft^d	0.5 ft	281	17.3
	Effluent	69	79.7
3. Tetrachloroethylene			
	Influent	39	
		42	
		46	
	Average:	42.3	
45:1	0.5 ft	30	29.1
	Effluent	0.6	98.6
25:1	0.5 ft	40	5.4
	Effluent	1.2	97.2
15:1	0.5 ft	33	22.0
	Effluent	2.6	93.9
8:1	0.5 ft	35	17.3
	Effluent	5.0	88.2

TABLE C-4

GLEN COVE, N.Y., PILOT PLANT
PHASE III
U.S. EPA Packed Column Air Stripper
(All Values in ug/l)

B. Using 2" (5.0 cm) Plastic Saddles As Packing - Testing Date: 12/14/82 (Continued)

Air to Water Ratio	Sample Port Location	Concentrations	Percent Removal
5:1	0.5 ft	35	17.3
	Effluent	7.7	81.8
Natural Draft[d]	0.5 ft	32	24.3
	Effluent	4.2	90.1
4. 1,1,1-Trichloroethane			
	Influent	2.7	
		3.1	
		3.2	
	Average:	3.0	
45:1	0.5 ft	3.0	-
	Effluent	<0.5	> 83.3
25:1	0.5 ft	3.4	-
	Effluent	0.5	83.3
15:1	0.5 ft	2.8	6.7
	Effluent	0.5	83.3
8:1	0.5 ft	3.1	-
	Effluent	0.9	70.0
5:1	0.5 ft	3.1	-
	Effluent	1.3	56.7
Natural Draft[d]	0.5 ft	2.7	10.0
	Effluent	1.3	56.7

C-5 AERATION SYSTEMS

Suspended Solids & Particulate Counts

TABLE C-5

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AERATION SYSTEMS

Suspended Solids Counts

The results of the suspended solids analyses on the influent and effluent of all test units sampled were less than 0.1 mg/L, which is the accuracy of the analytical equipment (Balance) utilized.

Particulate Counts

The following is the average of the total particulate count analyses performed at the U.S. EPA Laboratories in Cincinnati, Ohio.

The apparatus utilized was a Delta Counter having 12 channels and a um range from 2.5 to 150.

Location	Date	Average Particulate Levels Counts/10 mL
1. U.S. EPA Packed Column Air Stripper		
A. Influent	8/20/82	623.2
B. Effluent	8/20/82	438.25
2. Well No. 22 (Influent)	10/21/82	100
A. Diffused Aeration Column Effluent	10/21/82	195
B. Spray Aeration Column Effluent	10/21/82	92
3. Well No. 20 (Influent)	10/21/82	74,124
Air-lift Pump Effluent	10/21/82	2,252

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C-6 AIR SAMPLING RESULTS

1. New York Testing Laboratories, Inc. Report
2. Table Comparing Actual Analytical Value and Computed Theoretical Value

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NEW YORK TESTING LABORATORIES, INC.
CALL BOX 1021, 75 URBAN AVENUE, WESTBURY, N.Y. 11590 • (516) 334 7770 • (212) 297 1448 TWX 510 222 0283

Cover Page

Lab. No. 82-65518 (A)

RESULTS
OF
GAS SAMPLING

FOR

NEBOLSINE, KOHLMANN, RUGGIERO, ENGINEERS, P.C.
1250 BROADWAY
NEW YORK, NEW YORK 10001

11 MARCH 1983

ENVIRONMENTAL ELECTRONIC NON DESTRUCTIVE MATERIALS CHEMICAL ANALYSES AND POLLUTION CONTROL
CONSULTING ENGINEERING

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Page 1. Lab. No. 82-65518 (A)

CLIENT:	Nebolsine, Kohlmann, Ruggiero, Engineers, P.C. 1250 Broadway New York, New York 10001 Attention: Mr. Dominick Ruggiero, P.E.
CLIENT'S P.O. NO.:	Pending
MATERIAL:	Stack Gas
TEST FOR:	Chlorinated Hydrocarbons

I. BACKGROUND

New York Testing Laboratories, Inc. conducted an air sampling program in the facilities of Carney Street Water Plant, Carney Street, Glen Cove, New York, to determine the levels of Trichloroethylene, Tetrachloroethylene, Cis 1,2 Dichloroethylene, and 1,1,1, Trichloroethane.

A total of four (4) tests was conducted in several locations.

II. SAMPLING PROCEDURE

The sampling procedure followed is similar to the Environmental Protection Agency's Method 25 "Determination of Total Gaseous Nonmethane Organic Emissions as Carbon."

The sampling train is shown in Sketch No. 1. The train consisted of a 1/4" diameter stainless steel probe, an impinger (Midget) train, a rotameter, a vacuum pump and a gas bag.

II. SAMPLING PROCEDURE (Continued)

The impinger train had two impingers in series. The first one contained 10 ml of distilled water and the second one was left empty.

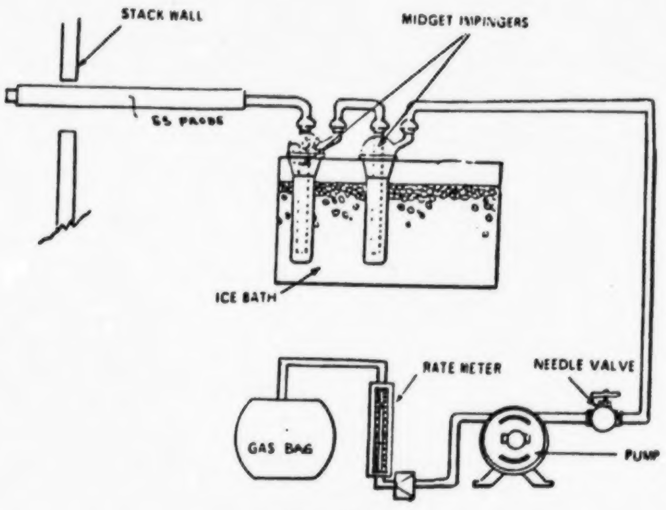
The pump was hooked up to the impinger train and the gas bag by means of Teflon tubing.

A total of one (1) run per emission point was made on each sampling date. Each run had a duration of approximately one (1) hour. Sampling rate of about 0.75 liter per minute was maintained.

At the end of each run, the condensate from the impinger train was volumetrically measured and poured into glass bottles. Each impinger and the probe were rinsed with distilled water and the washings placed in a separate bottle. All condensates, rinsing samples, and the gas bags were brought back to the laboratory for analysis.

Simultaneous with the sampling of the emission points, one (1) composite sample of the ambient air was collected in a one (1) cubic foot gas bag. This bag sample was likewise analyzed for the four (4) contaminants.

All samples were analyzed for the aforesaid contaminants by means of gas chromatography.


STACK WALL
MIDGET IMPINGERS
SS PROBE
ICE BATH
RATE METER
NEEDLE VALVE
GAS BAG
PUMP

sampling train

III. RESULTS

The following results were obtained from the tests:

Sampling done May 28, 1982

	Level, ppm (vol.)				
Cis 1,2 Dichloroethylene	Diffused Aeration Column	Spray Aeration Column	Air Lift Pump	Ambient Air	EPA Column
Condensible	ND	ND	ND	ND	--
Non Condensible	ND	ND	ND	ND	--
1,1,1 Trichloroethane					
Condensible	ND	ND	ND	ND	--
Non Condensible	ND	ND	ND	ND	--
Trichloroethylene					
Condensible	0.0001	ND	ND	ND	--
Non Condensible	6.5	ND	ND	ND	--
Tetrachloroethylene					
Condensible	0.0001	ND	ND	ND	--
Non Condensible	ND	ND	ND	ND	--

ND = None Detected

Sensitivity

Non Condensible	± 0.5 ppm
Condensible	± 0.001 ppm
Net Sensitivity	± 0.5 ppm

III. RESULTS (Continued)

The following results were obtained from the tests:

Sampling done August 20, 1982

	Level,ppm (vol.)				
	Diffused Aeration Column	Spray Aeration Column	Air Lift Pump	Ambient Air	EPA Column
Cis 1,2 Dichloroethylene					
Condensible	0.021	0.007	ND	--	0.039
Non Condensible	ND	ND	ND	ND	5.3
1,1,1 Trichloroethane					
Condensible	0.013	0.011	0.013	--	0.006
Non Condensible	ND	ND	ND	ND	ND
Trichloroethylene					
Condensible	0.010	0.001	0.002	--	9.7
Non Condensible	ND	ND	ND	ND	0.021
Tetrachloroethylene					
Condensible	0.001	ND	ND	--	0.001
Non Condensible	ND	ND	ND	ND	1.4

ND = None Detected

III. RESULTS (Continued)

The following results were obtained from the tests:

Sampling done November 16, 1982

Level,ppm (vol.)

	Diffused Aeration Column	Spray Aeration Column	Air Lift Pump	Ambient Air	EPA Column
Cis 1,2 Dichloroethylene					
Condensible	ND	ND	--	--	--
Non Condensible	5.7	ND	--	ND	--
1,1,1 Trichloroethane					
Condensible	ND	ND	--	--	--
Non Condensible	4.9	ND	--	ND	--
Trichloroethylene					
Condensible	ND	ND	--	--	--
Non Condensible	12.2	ND	--	ND	--
Tetrachloroethylene					
Condensible	ND	ND	--	--	--
Non Condensible	ND	ND	--	ND	--

ND = None Detected

III. RESULTS (Continued)

The following results were obtained from the tests:

Sampling done December 16, 1982

		Level,ppm (vol.)			
Cis 1,2 Dichloroethylene	Diffused Aeration Column	Spray Aeration Column	Air Lift Pump	Ambient Air	EPA Column
Condensible	0.017	ND	--	--	0.016
Non Condensible	9.6	ND	--	ND	12.6
1,1,1 Trichloroethane					
Condensible	ND	ND	--	--	ND
Non Condensible	ND	ND	--	ND	ND
Trichloroethylene					
Condensible	0.010	ND	--	--	0.008
Non Condensible	5.7	ND	--	ND	5.0
Tetrachloroethylene					
Condensible	ND	ND	--	--	ND
Non Condensible	ND	ND	--	ND	ND

ND = None Detected

III. RESULTS (Continued)

Miscellaneous Data

	Diffused Aeration Column	Spray Aeration	Air Lift Pump	EPA Column
May 28, 1982				
Vol. of Air Sampled, l	24.0	24.0	24.2	--
Vol. of Water in Condensible Trap, ml	10	10	10	--
Volume of Rinse Water, ml	221	220	221	--
August 20, 1982				
Vol. of Air Sampled, l	20.0	18.14	21.96	29.28
Vol. of Water in Condensible Trap, ml	10	10	10	10
Vol. of Rinse Water, ml	109	109	109	109
November 16, 1982				
Vol. of Air Sampled, l	23.0	23.0	23.0	23.0
Vol. of Water in Condensible Trap, ml	10	10	10	10
Vol. of Rinse Water, ml	110	110	110	110
December 16, 1982				
Vol. of Air Sampled, l	23.0	23.0	23.0	23.0
Vol. of Water in Condensible Trap, ml	10	10	10	10
Vol. of Rinse Water, ml	121.4	121.4	121.4	121.4

III. RESULTS (Continued)

There are no emission standards for stationary sources on the contaminants. Current OSHA standards for room air are as follows:

	Levels, ppm
Trichloroethylene	100
Tetrachloroethylene	100
1,2 Dichloroethylene	200
1,1,1 Trichloroethane	350

The results show that the contaminants detected are all within the only available standards.

IV. CERTIFICATION AND SIGNATURES

We certify that this report is a true and authentic report of results obtained from our tests.

Respectfully submitted,

NEW YORK TESTING LABORATORIES, INC.

Prepared by:
Benito P. San Pedro, P.E.
Director, Pollution Control Div.

Approved by:
G. J. Horvitz, P.E.
Chief Officer

eas

Report on sample by client applies only to sample
Report on samples by us applies only to lot sampled
Information contained herein is not to be used for reproduction except by special permission
Samples retained for thirty days maximum after date of report unless specifically requested otherwise by client. The liability of the New York Testing Laboratories, Inc. with respect to the services charged for herein, shall in no event exceed the amount of the invoice
FORM 200

TABLE C-6

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIR SAMPLING DATA EVALUATION

The following is a comparison between the air analysis performed by New York Testing Laboratories, Inc. and the calculated theoretical values.* The following notations were used in the tables:

Notation

cis 1,2 - Cis-1,2-Dichloroethylene
1,1,1 - 1,1,1-Trichloroethane
Tri - Trichloroethylene
Tetra - Tetrachloroethylene
Inf. - Water Influent value
Eff. - Water Effluent value
W.F. - Water flow in gpm
A.F. - Air flow in cfm
A/R - Air to water ratio
Diffused - Diffused aeration column
Spray - Spray aeration column
Air-Lift - Air lift pump
EPA-Column - U.S. EPA's packed aeration column
Amb - Ambient air conditions
N.D. - Non detectable (<0.5 ppm)

Air results in ppm (volume to volume)

Water results in ug/l.

---

* $$Yo = \frac{1}{7.48} \left(\frac{Q}{V}\right) (C_I - C_E) \left(\frac{24.04}{M}\right)$$

where Yo = Effluent air concentration (ug/L)
Q = Water flow rate (gpm)
V = Air flow rate (ft3/min)
C_I = Influent water contaminant concentration (ug/L)
C_E = Effluent water contaminant concentration (ug/L)
M = Molecular weight of contaminant

Reference: "Trace Organic Removal by Air Stripping," American Water Works Association Research Foundation.

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TABLE C-6

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIR SAMPLING DATA EVALUATION
(Continued)

	Actual Results	Computed Theoretical	Basis for Theoretical				
			Inf.	Eff.	W.F.	A.F.	A/R
I. May 28, 1982							
A. Diffused							
cis 1,2	N.D.	2.33	118	43	28	30	8/1
1,1,1	N.D.	0.056	3.1	0.6	"	"	"
Tri	6.5001	3.575	200	46	"	"	"
Tetra	N.D.	0.5309	35	5.7	"	"	"
B. Spray							
cis 1,2	N.D.	0.009	118	48	10	2500	1870/1
1,1,1	N.D.	0.00016	3.1	1.4	"	"	"
Tri	N.D.	0.0103	200	96	"	"	"
Tetra	N.D.	0.0014	35	17	"	"	"
C. Air-lift							
cis 1,2	N.D.)	Not Calculated					
1,1,1	N.D.)						
Tri	N.D.)						
Tetra	N.D.)						
D. Amb							
cis 1,2	N.D.)	Not Calculated					
1,1,1	N.D.)						
Tri	N.D.)						
Tetra	N.D.)						

TABLE C-6

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIR SAMPLING DATA EVALUATION
(Continued)

	Actual Results	Computed Theoretical	Basis for Theoretical				
			Inf.	Eff.	W.F.	A.F.	A/R
II. August 20, 1982							
A. EPA Column							
cis 1,2	5.3	2.28	161	19	125	258	15/1
1,1,1	N.D.	0.023	2.7	0.7	"	"	"
Tri	9.7	2.95	257	7.7	"	"	"
Tetra	1.4	0.36	38	1.0	"	"	"
B. Diffused							
cis 1,2	N.D.	1.46	114	26	28	56	15/1
1,1,1	N.D.	0.023	2.4	0.5	"	"	"
Tri	N.D.	2.122	192	18	"	"	"
Tetra	N.D.	0.346	38	2.2	"	"	"
C. Spray							
cis 1,2	N.D.	0.022	114	55	28	2500	668/1
1,1,1	N.D.	0.00038	2.4	1.0	"	"	"
Tri	N.D.	0.0279	192	90	"	"	"
Tetra	N.D.	0.0043	38	18	"	"	"
D. Air Lift							
cis 1,2	N.D.)	Not Calculated					
1,1,1	N.D.)						
Tri	N.D.)						
Tetra	N.D.)						
E. Amb							
cis 1,2	N.D.)	Not Calculated					
1,1,1	N.D.)						
Tri	N.D.)						
Tetra	N.D.)						

TABLE C-6

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIR SAMPLING DATA EVALUATION
(Continued)

	Actual Results	Computed Theoretical	Basis for Theoretical				
			Inf.	Eff.	W.F.	A.F.	A/R
III. November 16, 1982							
A. Diffused							
cis 1,2	5.7	1.6	159.5	62.8	28	56	15/1
1,1,1	4.9	0.02	2.6	1.0	"	"	"
Tri	12.2	2.42	247	50.8	"	"	"
Tetra	1	0.32	37	4.4	"	"	"
B. Spray							
cis 1,2	N.D.	0.017	158	5.2	8.2	2500	2380/1
1,1,1	N.D.	0.00051	1.9	0.5	"	"	"
Tri	N.D.	0.0124	247	9.3	"	"	"
Tetra	N.D.	0.0023	38	2.1	"	"	"
C. Amb							
cis 1,2	N.D.	Not Calculated					
1,1,1	N.D.						
Tri	N.D.						
Tetra	N.D.						

TABLE C-6

GLEN COVE, N.Y., PILOT PLANT
PHASE III
AIR SAMPLING DATA EVALUATION
(Continued)

	Actual Results	Computed Theoretical	Inf.	Eff.	W.F.	A.F.	A/R
IV. December 16, 1982							
A. EPA Column							
cis 1,2	12.616	1.70	204	13	84.8	316	27.8/1
1,1,1	N.D.	0.019	3.5	0.5	"	"	"
Tri	5.008	2.11	331	10	"	"	"
Tetra	N.D.	0.21	40	1.2	"	"	"
B. Diffused							
cis 1,2	9.77	1.96	215.5	69.3	28	56	15/1
1,1,1	N.D.	0.042	4.4	0.85	"	"	"
Tri	5.71	2.83	298.5	65	"	"	"
Tetra	N.D.	0.355	41.5	4.6	"	"	"
C. Spray							
cis 1,2	N.D.	0.028	215.5	4.9	10	2500	1870/1
1,1,1	N.D.	0.00038	4.4	0.5	"	"	"
Tri	N.D.	0.0283	298.5	8.8	"	"	"
Tetra	N.D.	0.0031	41.5	1.2	"	"	"
D. Amb							
cis 1,2	N.D.)	Not Calculated					
1,1,1	N.D.)						
Tri	N.D.)						
Tetra	N.D.)						

PHASE III REPORT:

APPENDIX D
COMPARATIVE SCREEN ANALYSIS
OF
AMBERSORB® XE 340 RESIN

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INDEPENDENCE MALL WEST PHILADELPHIA PA 19105 U.S.A. TELEPHONE (215) 592-3000
· CABLE ADDRESS ROHMHAAS TELEX 845-247

REPLY TO
RESEARCH LABORATORIES
727 NORRISTOWN ROAD
SPRING HOUSE, PA 19477
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ROHM
HAAS
COMPANY

March 29, 1982

Dominick Ruggiero
Nebolsine Kohlmann Ruggiero Engineers
1250 Broadway
New York, New York 10001

Dear Dominick:

We have examined the "suspect" lot of Ambersorb XE 340 (#2-9387) and have determined that the particle size distribution is significantly different than the material used in Phases I and II at Glen Cove. As the data in Table 1 and Figure 1 show, the "suspect" material contains many more large (-16+30) beads than the other Ambersorb XE 340 lots described.

Although, as shown in Figure 2, the isotherm for trichloroethylene shows that this material has a higher equilibrium capacity than Lot #001 (Phases I and II), it becomes obvious that it does not perform as well kinetically due to its larger particle size. This kinetic effect becomes more important at even higher flow rates. Even at 4 gpm/ft^3, this effect is dramatic.

I have checked with our product development people and have discovered that this material had been improperly screened. I will include a particle size quality control specification for our production facility to guarantee that this unfortunate error does not re-occur.

I have delivered one cubic foot of Ambersorb XE 340 (Lot #JJM 2998A) to the Glen Cove pilot plant. I fully expect that this material will perform satisfactorily.

Again, I would like to apologize for the inconvenience that this error has caused.

Sincerely,

Eric

Eric G. Isacoff

EGI/bb
Attachments
cc: W.A. Feige-U.S. EPA
C.A. Panza

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TABLE 1 - COMPARATIVE SCREEN ANALYSIS - AMBERSORB XE 340

Mesh Cut	Lot #001 (Phase I & II)		Lot #2-9387 (Phase III)		Lot #2-0200		Lot #JJM 2998A	
	% Retained	Cum. %	% Retained	Cum. %	% Retained	Cum. %	% Retained	Cum. %
-16+20	2.67%	2.67%	7.12%	7.12%	0	0	0	0
-20+30	39.08	41.84	57.80	64.92	44.40%	44.40%	42.92%	42.92%
-30+40	41.02	82.86	25.58	90.50	33.50	77.90	42.53	85.47
-40+50	13.98	96.84	9.47	99.97	18.53	96.43	13.41	98.88
-50+60	2.47	99.31	-	-	3.53	99.96	1.11	99.99
-60+80	0.66	99.97	-	-	-	-	-	-

FIGURE 1 SCREEN ANALYSIS (DRY) - AMBERSORB XE340

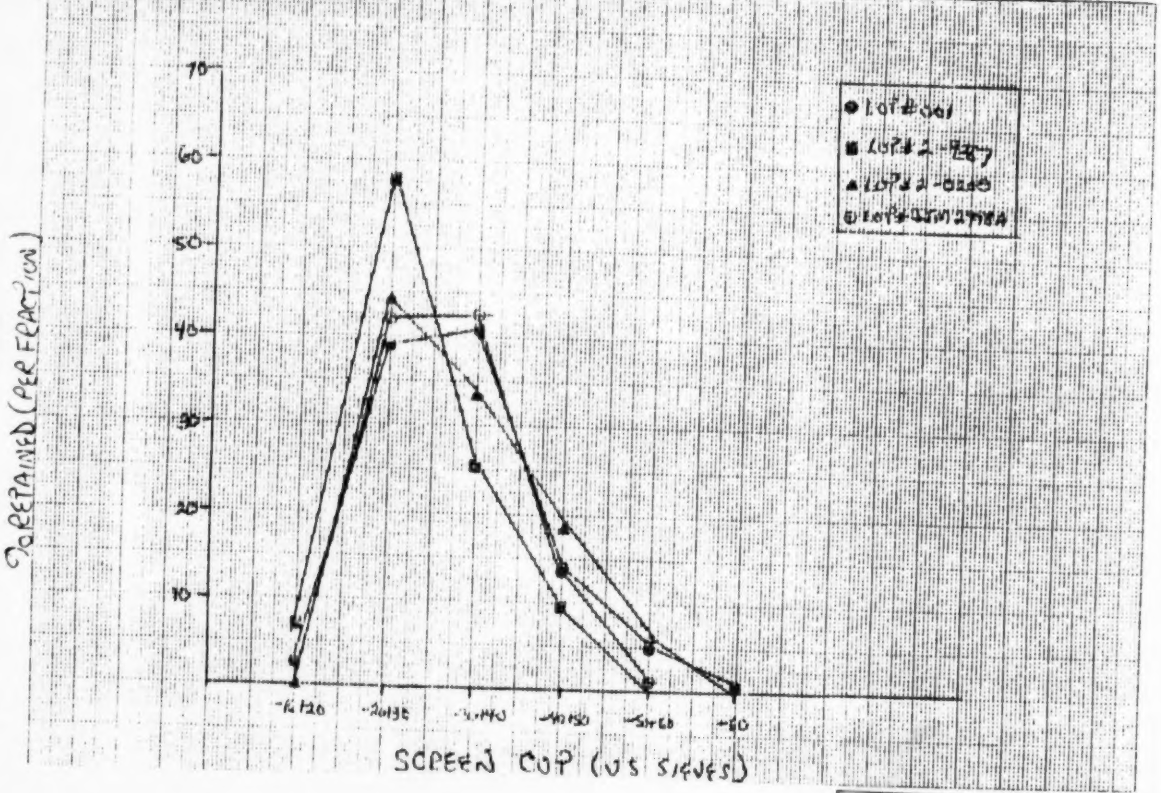

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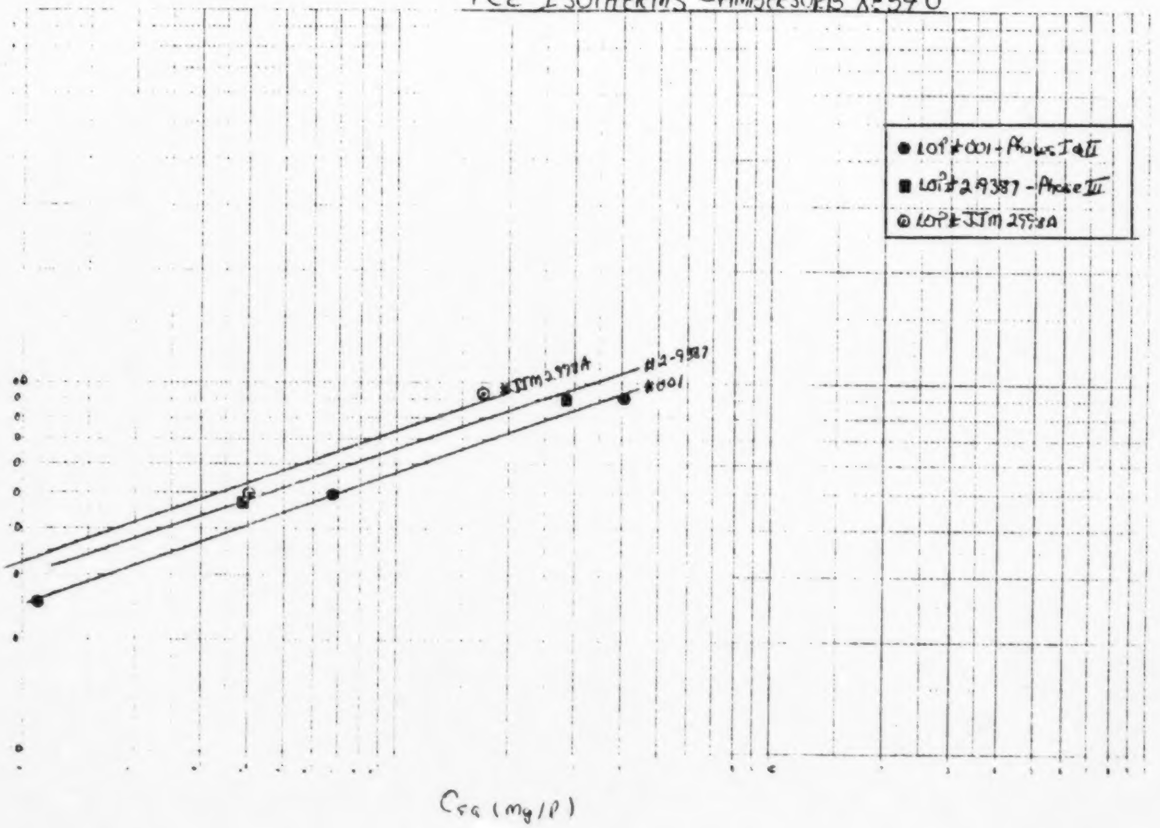
FIGURE 2

TCE ISOTHERMS - AMBERSORB XE340



PHASE III REPORT:

APPENDIX E

RESIN ADSORPTION TESTING RESULTS

E-1 RESIN WITHOUT PRIOR AERATION

E-2 RESIN WITH PRIOR AERATION

TABLE E-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
RESULTS OF RESIN COLUMNS I, II, III, IV - NO AERATION
(USING ACCEPTABLE RESIN)

(All results in ug/l)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra
Column I regenerated from 9/25/81 to 10/6/81							
1	2	10/16/81	INF-201	71	2.3	185	42
			I-RCE-201	<0.5	<0.5	<0.5	<0.5
2	6	10/20/81	INF-202	78	2.8	197	151
			I-RCE-202	3.4	1.5	2.8	4.3
3	8	10/22/81	INF-203	75	2.8	185	39
			I-RCE-203	1.0	<0.5	1.1	1.2
4	13	10/27/81	INF-204	75	2.7	184	41
			I-RCE-204	3.5	2.4	3.2	3.2
5	15	10/29/81	INF-205	72	2.8	182	34
			I-RCE-205	14	2.5	11	7.0
6	20	11/03/81	INF-206	71	2.6	164	35
			I-RCE-206	12	1.8	5.7	4.8
7	22	11/05/81	INF-207	81	2.9	190	40
			I-RCE-207	16	1.7	18	13
8	26	11/09/81	INF-208	90	2.9	172	34
			I-RCE-208	16	1.1	9.0	4.5
9	29	11/12/81	INF-209	93	3.0	187	34
			I-RCE-209	22	1.5	13	6.4
10	33	11/16/81	INF-210	96	3.1	189	37
			I-RCE-210	28	1.7	16	7.2
11	35	11/18/81	INF-211	100	3.3	197	40
			I-RCE-211	40	2.8	25	11
12	41	11/24/81	INF-212	99	3.2	194	42
			I-RCE-212	46	2.3	18	7.0
13	51	12/04/81	INF-213	93	2.4	175	36
			I-RCE-213	59	2.4	40	29
14	57	12/10/81	INF-214	101	3.3	184	51
			I-RCE-214	62	1.8	33	7.6
15	65	12/18/81	INF-215	105	3.2	187	46
			I-RCE-215	79	2.5	62	43
16	71	12/24/81	INF-216	94	2.9	172	44
			I-RCE-216	80	2.4	62	19
17	76	12/29/81	INF-217	95	2.9	173	45
			I-RCE-217	90	2.1	63	16
18	83	1/05/82	INF-218	96	2.8	175	45
			I-RCE-218	95	2.5	82	24
19	89	1/11/82	INF-219	105	2.3	202	50
			I-RCE-219	96	2.0	70	19
20	96	1/18/82	INF-220	97	2.3	188	43
			I-RCE-220	99	1.6	77	16
21	103	1/25/82	INF-221	100	2.1	186	42
			I-RCE-221	99	1.5	83	16

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TABLE E-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
RESULTS OF RESIN COLUMNS I, II, III, IV - NO AERATION
(USING ACCEPTABLE RESIN)

(All results in ug/1)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra
22	110	2/01/82	INF-222	101	2.2	191	40
			I-RCE-222	111	1.8	79	24
Column I regenerated from 2/2/82 to 2/3/82							
	1	2/04/82	I-RCE-2/4	0.8	<0.5	0.6	1.6
	2	2/05/82	I-RCE-2/5	0.7	<0.5	0.8	2.2
23	117	2/08/82	INF-223	109	2.3	198	46
	5		I-RCE-223	2.0	<0.5	2.1	3.0
	7	2/10/82	I-RCE-2/10	6.4	1.4	13	9.2
	13	2/16/82	I-RCE-2/16	14	1.8	15	10
24	125	2/17/82	INF-224	132	2.7	208	44
	14		I-RCE-224	13	1.5	8.9	6.6
25	131	2/23/82	INF-225	123	2.5	202	40
	20		I-RCE-225	18	0.9	13	6.7
26	139	3/03/82	INF-226	131	2.7	214	45
	28		I-RCE-226	32	1.2	18	8.2
27	144	3/08/82	INF-227	131	2.7	211	44
	33		I-RCE-227	46	1.5	26	11
28	155	3/19/82	INF-228	121	2.9	234	48
	44		I-RCE-228	73	1.6	34	12
29		3/23/82	INF-229	127	2.9	238	56
	48		I-RCE-229	82	1.9	49	30
30	165	3/29/82	INF-230	132	3.1	253	51
	54		I-RCE-230	94	2.0	69	32
Columns II and IV put on line after being filled with fresh resin on 3/31/82 (water application rate Column II = 4 gpm/ft3; water application rate Column IV = 8 gpm/ft3).							
31	172	4/05/82	INF-231	124	2.3	224	49
	61		I-RCE-231	117	1.6	56	13
	5		II-RCE-231	0.7	1.1	< 0.5	< 0.5
	5		IV-RCE-231	13	1.5	2.1	1.7
32	179	4/12/82	INF-232	112	2.4	201	38
	68		I-RCE-232	97	2.2	66	16
	12		II-RCE-232	5.2	1.3	< 0.5	< 0.5
	12		IV-RCE-232	46	1.9	2.1	9.0
33	187	4/20/82	INF-233	130	2.5	210	50
	76		I-RCE-233	142	2.3	63	13
	20		II-RCE-233	24	2.0	3.0	1.5
	20		IV-RCE-233	90	2.1	66	16
34	193	4/26/82	INF-234	132	2.3	208	42
	82		I-RCE-234	138	1.4	60	15
	26		II-RCE-234	37	1.5	5.4	2.8
	26		IV-RCE-234	104	2.1	70	15
35	200	5/03/82	INF-235	146	2.3	188	37
	89		I-RCE-235	154	1.7	89	16
	33		II-RCE-235	55	1.4	8.8	2.5
	33		IV-RCE-235	119	1.5	91	19

TABLE E-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
RESULTS OF RESIN COLUMNS I, II, III, IV - NO AERATION
(USING ACCEPTABLE RESIN)

(All results in ug/l)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra
36	207	5/10/82	INF-236	136	2.9	183	37
	96		I-RCE-236	156	2.5	83	16
	40		II-RCE-236	80	1.6	19	5.2
	40		IV-RCE-236	126	1.4	83	18
37	211	5/14/82	INF-237	119	3.0	216	38
	100		I-RCE-237	131	1.6	103	19
	44		II-RCE-237	69	1.3	17	4.4
	44		IV-RCE-237	112	1.6	121	20
38	218	5/21/82	INF-238	113	2.9	204	34
	107		I-RCE-238	127	1.5	97	14
	51		II-RCE-238	81	1.3	22	4.8
	51		IV-RCE-238	116	1.6	127	21
39	225	5/28/82	INF-239	118	3.1	200	35
	114		I-RCE-239	139	1.6	118	17
	58		II-RCE-239	97	1.5	38	7.7
	58		IV-RCE-239	124	1.6	134	22

Column I regenerated with solvent from 6/3/82 to 6/4/82.
Columns III and IV put on line after being filled with fresh resin on 6/4/82.
(Water application rate to Column III = 2 gpm/ft^3; water application rate to Column IV = 6 gpm/ft^3).

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra
40	235	6/07/82	INF-240	125	3.2	212	50
	3		I-RCE-240	1.6	1.0	0.5	<0.5
	68		II-RCE-240	108	2.1	57	9.7
	3		III-RCE-240	N.M.	<0.5	<0.5	<0.5
	3		IV-RCE-240	0.6	1.1	<0.5	<0.5
41	243	6/15/82	INF-241	115	3.3	216	42
	11		I-RCE-241	7.1	1.5	1.2	2.0
	76		II-RCE-241	120	2.2	72	12
	11		III-RCE-241	<0.5	<0.5	<0.5	<0.5
	11		IV-RCE-241	19	2.3	1.3	1.0
42	250	6/22/82	INF-242	149	3.5	214	43
	18		I-RCE-242	22	1.9	3.5	4.3
	83		II-RCE-242	132	2.3	79	12
	18		III-RCE-242	<0.5	<0.5	N.M.	<0.5
	18		IV-RCE-242	45	1.8	11	4.2
43	259	7/01/82	INF-243	134	3.2	198	43
	27		I-RCE-243	43	1.8	14	7.8
	92		II-RCE-243	138	2.4	90	13
	27		III-RCE-243	<0.5	1.4	<0.5	<0.5
	27		IV-RCE-243	84	2.2	25	2.9
44	266	7/08/82	INF-244	138	3.3	207	41
	34		I-RCE-244	56	1.7	18	4.1
	99		II-RCE-244	150	1.7	84	12
	34		III-RCE-244	1.0	1.7	<0.5	<0.5
	34		IV-RCE-244	103	2.4	38	4.3
45	272	7/14/82	INF-245	138	1.7	197	41
	40		I-RCE-245	73	2.4	28	5.6
	105		II-RCE-245	151	1.5	92	14
	40		III-RCE-245	2.5	2.0	<0.5	<0.5
	40		IV-RCE-245	125	2.6	54	5.1
46	287	7/29/82	INF-246	129	3.4	200	40
	55		I-RCE-246	130	1.7	57	14
	120		II-RCE-246	141	3.1	112	10
	55		III-RCE-246	15	0.6	<0.5	<0.5
	55		IV-RCE-246	110	1.4	78	10

Column II regenerated from 8/3/82 to 8/4/82.

TABLE E-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
RESULTS OF RESIN COLUMNS I, II, III, IV - NO AERATION
(USING ACCEPTABLE RESIN)

(All results in ug/l)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra
47	302	8/12/82	INF-247	121	2.5	186	33
	69		I-RCE-247	110	1.4	59	11
	8		II-RCE-247	3.9	0.6	1.1	1.0
	69		III-RCE-247	32	0.6	<0.5	< 0.5
	69		IV-RCE-247	149	1.8	91	14
48	317	8/27/82	INF-248	123	2.7	212	36
	84		I-RCE-248	152	1.2	65	11
	23		II-RCE-248	14	0.9	2.1	2.6
	84		III-RCE-248	57	2.1	2.0	<0.5
	84		IV-RCE-248	143	1.6	121	14
49	330	9/09/82	INF-249	151	2.6	198	46
	97		I-RCE-249	142	1.6	71	11
	36		II-RCE-249	35	1.4	3.8	2.2
	97		III-RCE-249	95	1.9	3.1	0.5
	97		IV-RCE-249	145	1.7	118	13
50	338	9/17/82	INF-250	108	2.5	183	31
	105		I-RCE-250	143	1.5	84	13
	44		II-RCE-250	80	1.6	12	4.7
	105		III-RCE-250	37	1.5	4.8	0.5
	105		IV-RCE-250	136	1.4	119	19
51	351	9/30/82	INF-251	134	2.8	227	43
	118		I-RCE-251	169	1.3	78	10
	57		II-RCE-251	120	2.0	16	3.6
	118		III-RCE-251	107	1.6	7.7	0.6
	118		IV-RCE-251	137	1.3	114	13
52	366	10/15/82	INF-252	149	2.5	207	32
	133		I-RCE-252	160	1.8	105	16
	72		II-RCE-252	150	2.4	55	14
	133		III-RCE-252	148	2.3	11	0.7
	133		IV-RCE-252	151	1.6	166	17
Column I regenerated from 10/28/82 to 10/29/82.							
	0		I-RCE-10/29	0.5	1.0	0.6	0.5
53	383	11/01/82	INF-253	151	2.6	222	32
	3		I-RCE-253	1.5	0.9	1.1	0.5
	89		II-RCE-253	181	2.8	92	9.7
	150		III-RCE-253	166	2.1	23	2.0
Column IV regenerated after superloading from 11/1/82 to 11/2/82.							
			IV-RCE-11/2	9.6	0.8	5.1	0.7
54	398	11/16/82	INF-254	158	1.9	247	38
	18		I-RCE-254	12	1.2	4.1	4.0
	104		II-RCE-254	180	2.1	79	6.9
	165		III-RCE-254	175	1.8	31	2.4
	14		IV-RCE-254	64	1.1	34	9.2
55	413	12/01/82	INF-255	214	2.5	305	45
	33		I-RCE-255	72	2.0	31	13
	119		II-RCE-255	190	2.0	130	13
	180		III-RCE-255	180	1.5	45	10
	29		IV-RCE-255	127	2.6	63	13
56	426	12/14/82	INF-256	213	2.6	309	39
	46		I-RCE-256	117	2.3	24	6.4
	42		IV-RCE-256	195	3.5	94	9.9

TABLE E-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
RESULTS OF RESIN COLUMNS I, II, III, IV - NO AERATION
(USING ACCEPTABLE RESIN)

(All results in ug/l)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	Tri	Tetra
57	428	12/16/82	INF-257	216	2.7	301	41
	48		I-RCE-257	147	3.0	85	15
	134		II-RCE-257	206	3.3	189	15
	195		III-RCE-257	206	3.2	85	5.1
	44		IV-RCE-257	188	2.8	133	15

TABLE E-2

GLEN COVE, N.Y., PILOT PLANT
PHASE III
RESULTS OF RESIN COLUMNS V, VI, VII AFTER AERATION
(USING ACCEPTABLE RESIN)
(All results in ug/l)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
40		6/07/82	I-ACE-240	56	0.6	47	9.0	8:1
1	3		V-RCE-240	0.5	0.5	0.5	0.5	
1	3		VI-RCE-240	0.5	0.5	0.5	0.5	
1	3		VII-RCE-240	0.5	0.5	0.5	0.5	
41		6/15/82	I-ACE-241	50	0.5	41	5.5	8:1
2	11		V-RCE-241	0.5	0.5	0.5	0.5	
2	11		VI-RCE-241	1.2	0.5	0.5	0.5	
2	11		VII-RCE-241	7.8	0.8	0.7	0.5	
42		6/22/82	I-ACE-242	55	0.6	45	6.3	8:1
3	18		V-RCE-242	0.5	0.5	0.5	0.5	
3	18		VI-RCE-242	7.3	0.5	0.6	0.9	
3	18		VII-RCE-242	16	0.9	3.7	1.0	
43		7/01/82	I-ACE-243	53	0.6	43	6.3	8:1
4	27		V-RCE-243	0.8	0.5	0.5	0.5	
4	27		VI-RCE-243	7.1	0.6	0.5	0.5	
4	27		VII-RCE-243	15	1.1	2.8	1.3	
44		7/08/82	I-ACE-244	56	0.7	46	5.7	8:1
5	34		V-RCE-244	3.3	0.5	0.5	0.5	
5	34		VI-RCE-244	19	0.5	4.9	1.1	
5	34		VII-RCE-244	28	0.5	7.9	1.5	
45		7/14/82	I-ACE-245	48	0.7	44	4.3	8:1
6	40		V-RCE-245	7.6	0.8	0.5	0.5	
6	40		VI-RCE-245	22	0.5	5.6	1.1	
6	40		VII-RCE-245	32	0.5	10	1.9	
47		7/29/82	I-ACE-247	33	0.5	29	2.0	15:1
7	55		V-RCE-247	15	0.5	1.3	0.5	
7	55		VI-RCE-247	27	0.6	7.7	1.1	
7	55		VII-RCE-247	30	0.5	11	1.5	
49		8/12/82	I-ACE-249	32	0.6	27	2.8	15:1
8	69		V-RCE-249	19	0.5	2.4	0.9	
8	69		VI-RCE-249	27	0.7	8.5	0.7	
8	69		VII-RCE-249	33	0.5	9.9	1.2	
51		8/27/82	I-ACE-251	47	0.8	37	3.9	15:1
9	84		V-RCE-251	20	0.6	3.4	0.5	
9	84		VI-RCE-251	34	0.8	11	1.2	
9	84		VII-RCE-251	35	0.8	15	2.2	
53		9/09/82	I-ACE-253	31	0.5	27	4.3	15:1
10	97		V-RCE-253	25	0.7	4.4	0.5	
10	97		VI-RCE-253	36	1.0	14	1.3	
10	97		VII-RCE-253	37	0.8	18	3.0	
54		9/17/82	I-ACE-254	33	0.7	34	5.8	15:1
11	105		V-RCE-254	29	0.5	4.3	0.6	
11	105		VI-RCE-254	36	0.5	12	1.4	
11	105		VII-RCE-254	41	0.5	18	2.0	
56		9/30/82	I-ACE-256	50	0.8	46	4.8	15:1
12	118		V-RCE-256	33	0.5	7.5	1.1	
12	118		VI-RCE-256	43	0.5	16	1.9	
12	118		VII-RCE-256	47	0.6	21	2.3	
58		10/15/82	I-ACE-258	56	0.9	57	5.2	15:1
13	133		V-RCE-258	40	0.8	6.5	1.1	
13	133		VI-RCE-258	50	0.8	20	1.7	
13	133		VII-RCE-258	53	1.0	31	2.8	

NOTES: Column V: Flow Rate = 4 gpm/ft^3
Column VI: Flow Rate = 6 gpm/ft^3
Column VII: Flow Rate = 8 gpm/ft^3

TABLE E-2

GLEN COVE, N.Y., PILOT PLANT
PHASE III
RESULTS OF RESIN COLUMNS V. VI, VII AFTER AERATION
(USING ACCEPTABLE RESIN)
(All results in ug/l)
(Continued)

Sample Day	Days in Operation	Date	Sample	cis	1,1,1	tri	tetra	Ratio Air: Water
60		11/01/82	I-ACE-260	57	0.7	53	4.8	15:1
14	150		V-RCE-260	48	0.9	12	1.3	
14	150		VI-RCE-260	56	1.1	25	2.5	
14	150		VII-RCE-260	57	1.1	34	3.1	
62		11/16/82	I-ACE-262	64	1.0	50	5.0	15:1
15	165		V-RCE-262	49	0.9	10	0.8	
15	165		VI-RCE-262	48	0.9	23	1.7	
15	165		VII-RCE-262	54	0.8	33	2.6	
64		12/01/82	I-ACE-264	53	0.6	45	3.5	15:1
16	180		V-RCE-264	50	0.5	13	0.9	
16	180		VI-RCE-264	55	0.5	29	3.4	
16	180		VII-RCE-264	58	0.6	39	2.8	
67		12/16/82	I-ACE-267	73	1.0	80	5.4	15:1
17	195		V-RCE-267	60	1.2	21	2.3	
17	195		VI-RCE-267	70	1.3	42	3.3	
17	195		VII-RCE-267	73	1.3	50	4.3	

NOTES: Column V: Flow Rate = 4 gpm/ft^3
Column VI: Flow Rate = 6 gpm/ft^3
Column VII: Flow Rate = 8 gpm/ft^3

PHASE III REPORT:

APPENDIX F

GRANULAR ACTIVATED CARBON TESTING RESULTS

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TABLE F-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
ACTIVATED CARBON COLUMN RESULTS

(All results in ug/l)

Days in Operation	Date	Sample	cis	1,1,1	tri	tetra
5	1/18/82	INF-220	97	2.3	188	43
		CC1-220	23	0.6	1.2	0.5
		CC2-220	N.M.	N.M.	N.M.	N.M.
13	1/25/82	INF-221	100	2.1	186	42
		CC1-221	96	1.2	8.4	0.5
		CC2-221	9.2	N.M.	N.M.	N.M.
19	2/01/82	INF-222	101	2.2	191	40
		CC1-222	128	1.5	41	0.8
		CC2-222	70	0.9	N.M.	N.M.
26	2/08/82	INF-223	109	2.3	198	46
		CC1-223	125	1.4	39	0.5
		CC2-223	91	0.8	0.6	N.M.
35	2/17/82	INF-224	132	2.7	208	44
		CC1-224	152	1.4	93	1.2
		CC2-224	144	0.9	0.7	0.5
		CC3-224	81	1.3	0.7	0.5
41	2/23/82	INF-225	123	2.5	202	40
		CC1-225	135	1.3	125	1.6
		CC2-225	166	1.0	1.3	0.5
		CC3-225	123	0.5	N.M.	N.M.
49	3/03/82	INF-226	131	2.7	214	45
		CC1-226	145	1.3	166	2.9
		CC2-226	177	1.2	5.6	N.M.
		CC3-226	165	0.8	N.M.	N.M.
54	3/08/82	INF-227	131	2.7	211	44
		CC1-227	139	1.3	170	3.2
		CC2-228	185	1.3	10	0.5
		CC3-227	176	1.0	N.M.	0.5
65	3/19/82	INF-228	121	2.9	234	48
		CC1-228	149	1.4	200	5.0
		CC2-228	173	1.5	38	0.5
		CC3-228	193	1.1	0.5	N.M.
69	3/23/82	INF-229	127	2.9	238	56
		CC1-229	169	1.5	224	9.6
		CC2-229	174	1.6	58	N.M.
		CC3-229	200	1.4	0.5	N.M.
75	3/29/82	INF-230	132	3.1	253	51
		CC1-230	146	2.8	249	7.2
		CC2-230	164	3.1	84	0.5
		CC3-230	210	1.5	0.5	N.M.
82	4/05/82	INF-231	124	2.3	224	49
		CC1-231	149	3.0	259	3.8
		CC2-231	159	2.9	106	0.5
		CC3-231	192	3.1	1.0	N.M.
89	4/12/82	INF-232	112	2.4	201	38
		CC1-232	151	2.9	260	11
		CC2-232	160	3.2	147	0.5
		CC3-232	189	3.2	5.7	0.5

NOTES:
CC1 - Sample at 1 ft media depth
CC2 - Sample at 2 ft media depth
CC3 - Sample at 3 ft media depth
CC4 - Sample at 4 ft media depth
N.M.- Not measurable

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TABLE F-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
ACTIVATED CARBON COLUMN RESULTS
(Continued)
(All results in ug/l)

Days in Operation	Date	Sample	cis	1,1,1	tri	tetra
97	4/20/82	INF-233	130	2.5	210	50
		CC1-233	150	2.9	262	16
		CC2-233	156	3.2	196	0.5
		CC3-233	180	3.4	22	N.M.
103	4/26/82	INF-234	132	2.3	208	42
		CC1-234	139	2.7	212	14
		CC2-234	147	3.0	168	0.5
		CC3-234	177	3.6	30	N.M.
110	5/03/82	INF-235	146	2.3	188	37
		CC1-235	146	2.0	216	16
		CC2-235	160	2.3	206	0.6
		CC3-235	181	2.6	65	0.5
117	5/10/82	INF-236	136	2.9	183	37
		CC1-236	128	1.9	210	17
		CC2-236	128	2.2	224	0.6
		CC3-236	145	2.5	98	N.M.
		CC4-236	151	2.5	1.3	N.M.
121	5/14/82	INF-237	119	3.0	216	38
		CC1-237	133	2.3	245	20
		CC2-237	132	2.3	235	1.2
		CC3-237	138	2.1	102	N.M.
		CC4-237	140	1.9	3.2	0.5
128	5/21/82	INF-238	113	2.9	204	34
		CC1-238	121	1.6	239	24
		CC2-238	124	1.7	244	1.2
		CC3-238	130	2.1	125	N.M.
		CC4-238	146	2.1	13	N.M.
135	5/28/82	INF-239	118	3.1	200	35
		CC1-239	126	1.6	250	20
		CC2-239	127	1.7	253	1.5
		CC3-239	133	1.9	145	N.M.
		CC4-239	143	1.7	26	N.M.
145	6/07/82	INF-240	125	3.2	212	50
		CC1-240	121	1.6	238	21
		CC2-240	123	1.7	245	1.9
		CC3-240	138	2.0	173	0.5
		CC4-240	151	2.0	61	0.9
153	6/15/82	INF-241	115	3.3	216	42
		CC1-241	125	1.6	247	23
		CC2-241	128	1.9	213	2.9
		CC3-241	153	1.8	208	N.M.
		CC4-241	152	2.1	74	N.M.
160	6/22/82	INF-242	149	3.5	214	43
		CC1-242	132	1.9	213	24
		CC2-242	131	1.9	218	3.4
		CC3-242	142	2.0	210	0.5
		CC4-242	147	2.1	100	N.M.

NOTES: CC1 - Sample at 1 ft media depth
CC2 - Sample at 2 ft media depth
CC3 - Sample at 3 ft media depth
CC4 - Sample at 4 ft media depth
N.M.- Not measurable

TABLE F-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
ACTIVATED CARBON COLUMN RESULTS
(Continued)
(All results in ug/l)

Days in Operation	Date	Sample	cis	1,1,1	tri	tetra
169	7/01/82	INF-243	134	3.2	198	43
		CC1-243	147	1.8	228	27
		CC2-243	145	1.8	234	4.5
		CC3-243	147	2.1	233	0.5
		CC4-243	155	2.2	116	0.5
176	7/08/82	INF-244	138	3.3	207	41
		CC1-244	151	1.9	232	29
		CC2-244	150	2.0	244	7.0
		CC3-244	152	2.1	238	0.5
		CC4-244	154	2.2	132	N.M.
182	7/14/82	INF-245	138	1.7	197	41
		CC1-245	163	2.2	236	28
		CC2-245	167	2.3	258	4.6
		CC3-245	146	1.9	239	0.5
		CC4-245	156	2.2	152	5.3
197	7/29/82	INF-247	129	3.4	200	40
		CC1-247	145	1.9	219	31
		CC2-247	146	2.0	239	7.5
		CC3-247	149	2.0	247	0.5
		CC4-247	161	2.1	188	0.5
211	8/12/82	INF-249	121	2.5	186	33
		CC1-249	128	1.9	220	30
		CC2-249	122	1.8	223	7.6
		CC3-249	154	2.2	235	2.0
		CC4-249	142	2.2	204	0.5
226	8/27/82	INF-251	123	2.7	212	36
		CC1-251	126	1.6	216	30
		CC2-251	127	1.9	235	12
		CC3-251	171	2.4	260	3.8
		CC4-251	146	2.2	225	0.8
239	9/09/82	INF-253	151	2.6	198	46
		CC1-253	126	1.7	221	31
		CC2-253	142	2.3	256	23
		CC3-243	159	2.3	246	2.7
		CC4-253	152	2.2	236	2.1
247	9/17/82	INF-254	108	2.5	183	31
		CC1-254	150	1.6	222	28
		CC2-254	144	2.7	262	23
		CC3-254	170	2.2	249	3.6
		CC4-254	152	2.1	237	0.5
260	9/30/82	INF-256	134	2.8	227	43
		CC1-256	140	1.6	224	31
		CC2-256	159	2.3	267	20
		CC3-256	146	2.2	282	4.5
		CC4-256	155	2.2	247	1.1
275	10/15/82	INF-258	149	2.5	207	32
		CC1-258	172	2.8	267	39
		CC2-258	167	2.9	287	22
		CC3-258	171	3.2	319	7.3
		CC4-258	162	3.2	308	1.8

NOTES: CC1 - Sample at 1 ft media depth
CC2 - Sample at 2 ft media depth
CC3 - Sample at 3 ft media depth
CC4 - Sample at 4 ft media depth
N.M.- Not measurable

TABLE F-1

GLEN COVE, N.Y., PILOT PLANT
PHASE III
ACTIVATED CARBON COLUMN RESULTS
(Continued)

(All results in ug/l)

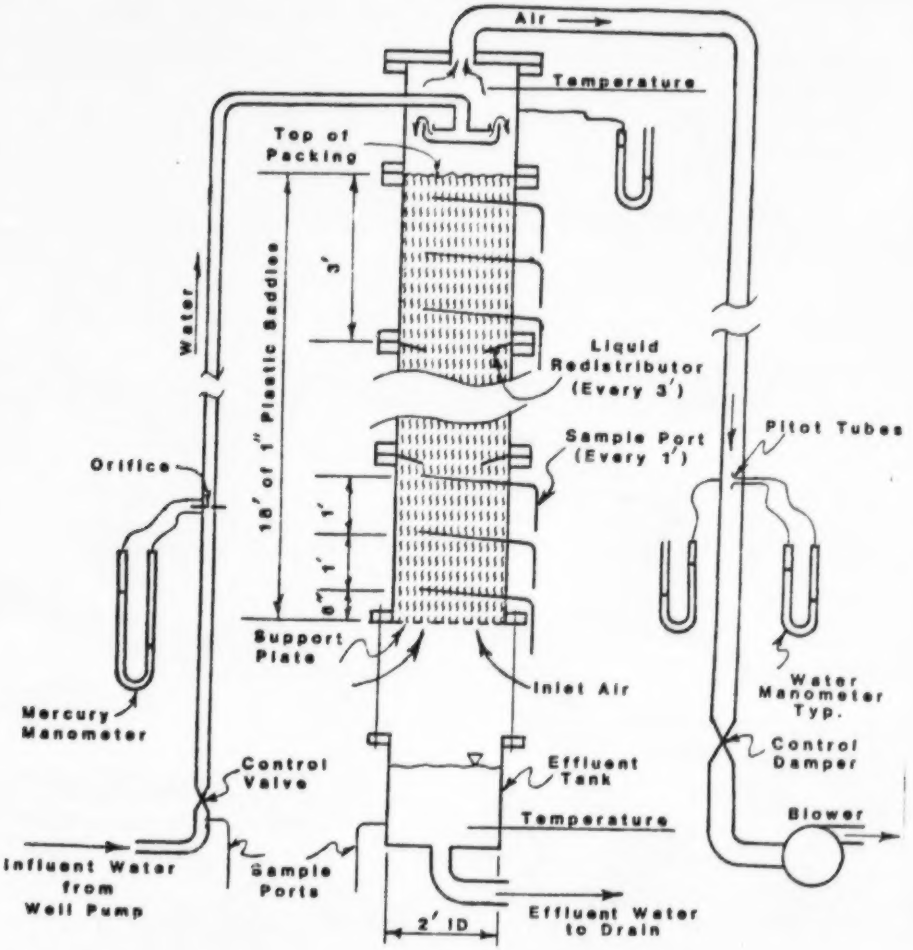
Days in Operation	Date	Sample	cis	1,1,1	tri	tetra
292	11/01/82	INF-260	151	2.6	222	32
		CC1-260	182	3.2	290	41
		CC2-260	190	3.3	305	31
		CC3-260	186	3.4	327	12
		CC4-260	173	3.3	322	3.2
307	11/16/82	INF-262	158	1.9	247	38
		CC1-262	181	1.9	276	36
		CC2-262	2.9	290	24	
		CC3-262	192	3.3	281	14
		CC4-262	194	3.3	292	5.9
322	12/01/82	INF-264	214	2.5	305	45
		CC1-264	177	3.0	249	34
		CC2-264	201	3.2	266	38
		CC3-264	208	3.4	273	15
		CC4-264	205	3.6	294	8.5

NOTES:
CC1 - Sample at 1 ft media depth
CC2 - Sample at 2 ft media depth
CC3 - Sample at 3 ft media depth
CC4 - Sample at 4 ft media depth

PHASE III REPORT:

APPENDIX G

U.S. EPA PACKED COLUMN AIR STRIPPING PILOT SYSTEM



Air →
Temperature
Top of Packing
18' of 1" Plastic Saddles
3'
Water →
Liquid Redistributor (Every 3')
Sample Port (Every 1')
Pitot Tubes
Orifice
1'
1'
6"
Support Plate
Inlet Air
Water Manometer Typ.
Mercury Manometer
Control Valve
Effluent Tank
Control Damper
Temperature
Blower
Influent Water from Well Pump
Sample Ports
Effluent Water to Drain
2' ID

PACKED COLUMN AIR STRIPPING PILOT SYSTEM

FIGURE G-1

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PHASE III REPORT:

APPENDIX H

MUNTERS COMPANY COMPUTER DATA

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TABLE H-1
THE MUNTERS CORPORATION COMPUTER DATA
TRICHLOROETHYLENE - AIR TO WATER RATIO 100:1

```
ENTER PROCESS REQUIREMENTS
AIR FLOW (ACFM),  WATER FLOW (MMGPD),  THM IN (MMG/L),  THM OUT (MMG/L),  TOWER PRESSURE(PSIA),  AIR TEMP,
9300                1                     227                10                  14.7                    55
                                                                                          water temp 55

PACKING DATA:
PACKING CODE,  PACKING SIZE,  PERCENT OF FLOODING VELOCITY,   (OR) TOWER I.D.
   1             12060            80                                  0


COST DATA:
ELECTRICITY ($/KWH),  PACKING ($/FT3),  STEEL ($/LB),  DEPRECIATION YEARS
.12                     15                 2                 10

WATER FLOW RATE IS:     19288. MOLES/HR       347500. LB/HR        694.4 GPM



    THE MINIMUM RATIO IS  0.4410 FT3/GAL,  OR     306.3  ACFM OF AIR

    THE ACTUAL AIR FLOW RATE IS    9300.0 ACFM,  OR  30.367 TIMES THE MINIMUM

TOWER I.D. IS  5.407 FT
OPERATING AT  80.00 PERCENT OF FLOODING



     GAS MASS VELOCITY =    0.538 LB/SEC-FT2
     LIQ MASS VELOCITY =    4.203 LB/SEC-FT2

     GAS LINEAR VELOCITY =   6.76 FT/SEC
     LIQUID RATE         =  30.43 GPM/FT2

HEIGHT        Y(GAS)         X(LIQ)       NTU          D P          KGA          KLA          KOGA

 0.0         0.0           0.100E+02     0.0          0.0
 2.75        0.107E+00     0.208E+02     0.025        1.116       2.7683      70.0225       0.0424
 4.29        0.215E+00     0.317E+02     0.040        1.742       2.7683      70.0225       0.0424
 5.37        0.322E+00     0.425E+02     0.050        2.183       2.7683      70.0225       0.0424
 6.22        0.429E+00     0.534E+02     0.058        2.525       2.7683      70.0225       0.0424
 6.89        0.536E+00     0.642E+02     0.065        2.800       2.7683      70.0225       0.0424
 7.47        0.644E+00     0.751E+02     0.070        3.033       2.7683      70.0225       0.0424
 7.96        0.751E+00     0.859E+02     0.075        3.235       2.7683      70.0225       0.0424
 8.40        0.858E+00     0.968E+02     0.079        3.412       2.7683      70.0225       0.0424
 8.79        0.965E+00     0.108E+03     0.083        3.570       2.7683      70.0225       0.0424
 9.14        0.107E+01     0.118E+03     0.086        3.713       2.7683      70.0225       0.0424
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TABLE H-1
THE MUNTERS CORPORATION COMPUTER DATA
TRICHLOROETHYLENE - AIR TO WATER RATIO 100:1
(Continued)

```
  9.46      0.118E+01   0.129E+03   0.089       3.844       2.7683     70.0225       0.0424
  9.76      0.129E+01   0.140E+03   0.092       3.964       2.7683     70.0225       0.0424
 10.03      0.139E+01   0.151E+03   0.095       4.075       2.7683     70.0225       0.0424
 10.29      0.150E+01   0.162E+03   0.097       4.179       2.7683     70.0225       0.0424
 10.53      0.161E+01   0.173E+03   0.100       4.275       2.7683     70.0225       0.0424
 10.75      0.172E+01   0.184E+03   0.102       4.366       2.7683     70.0225       0.0424
 10.96      0.182E+01   0.194E+03   0.104       4.452       2.7683     70.0225       0.0424
 11.16      0.193E+01   0.205E+03   0.106       4.533       2.7683     70.0225       0.0424
 11.35      0.204E+01   0.216E+03   0.107       4.609       2.7683     70.0225       0.0424
 11.53      0.215E+01   0.227E+03   0.109       4.682       2.7683     70.0225       0.0424


    M I S T   E L I M I N A T O R
    MATERIAL:  POLYPROPYLENE
    AREA:         6. FT2                WEIGHT:     20. POUNDS
    VELOCITY:  1521. FT/MIN           PRESSURE DROP:  0.853 INCHES H2O


    COSTS:
    T271:      6. FT2 AT $ 45.00/FT2                275.62 DOLLARS
    BLANKING PLATES:     17. FT2 AT $ 12.15/FT2     204.60 DOLLARS
                            SUBTOTAL                480.22 DOLLARS


    TOWER:
      5.41 FT I.D.  X  17.53 FT T-T  X   0.500 IN THICK
     7470.8 POUNDS  X   2.00 $/LB     =   14941.56 DOLLARS


     264.7 FT3 OF PACKING  X   15.00  =     3970.91 DOLLARS
                                          ----------------
 MIST ELIM. + PACKING + TOWER COST           19392.69 DOLLARS



    I N C R E M E N T A L   P O W E R   C O S T S  - PACKING ONLY
    COMPRESSOR:   9316.4 ACFM  X    5.54 INCHES W.C.  =    10.2 HORSEPOWER
    PUMP            698.8 GPM  X   11.53 FEET         =     2.5 HORSEPOWER


    ANNUAL OPERATING COSTS:
    COMPRESSOR  -   7952.77 DOLLARS
    PUMP        -   1980.67 DOLLARS
                    ---------
    TOTAL           9933.43 DOLLARS


    ANNUAL OWNING AND OPERATING COST IS  11872.70 DOLLARS
    OR $ 0.03253 / 1000 GALLONS
```

APPENDIX D

ANALYTICAL PROCEDURE AND QUALITY CONTROL

ANALYTICAL PROCEDURE AND OPERATIONS

As part of the testing program at Glen Cove, NKRE agreed to perform the analyses of the samples for halogenated hydrocarbons. For this purpose, a Tekmar LSC-1 sample concentrator and Tracor 560 gas chromatograph equipped with a 700A Hall electrolytic conductivity detector and mini-integrator with digital printer were purchased. This equipment was assembled and installed by a Tracor representative. During the second phase of the project a new recorder, (Varian four-speed recorder) was installed.

The analytical procedure followed was that specified by MERL "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants"

Standards were prepared by volume rather than by mass, a mutually agreeable deviation from the procedure. Tekmar recommended a purging time of 11 minutes, and this time was used throughout. Variations were made in the program for the gas chromatograph in order to effect better separation between cis-1,2-dichloroethylene and 1,1,1-trichloroethane.

Stock solutions of each contaminant in methanol were prepared every two months. Every two weeks, standard solutions containing all the pollutants were prepared from these stock solutions by further dilution in methanol. The concentration of contaminants in the samples were determined by comparison to these standards.

An independent quality assurance standard was prepared. It was analyzed ten times to determine the concentrations of its three main constituents (cis-1,2-dichloroethylene, trichloroethylene and tetrachloroethylene) and their respective standard deviations. Quality control charts, having limits of ± 2 standard deviations were then constructed. For the first few weeks of operation, this quality assurance sample was tested every other day. Later, testing was reduced to semi-weekly and eventually to weekly checks. Occasionally, samples that were analyzed in this laboratory also were analyzed at MERL in Cincinnati or for Nassau County at Stonybrook, L.I. (SUNY). In addition, special control samples were prepared for this field work which contained only the four pollutants found in the well water. These also served as a check of the accuracy of the laboratory analyses.

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Because the sensitivity of the gas chromatograph varied from day to day, appropriate standards were analyzed daily. The areas of the peaks of the standard had to be within a factor of two (-500, +100%) of the areas of the samples being analyzed. If the sample fell outside the standard's range, a different standard was used. Calculation of the concentration assumed a linear relationship within the concentration range involved, where C = concentration and A = area:

$$C_{sample} = C_{standard} \, (A_{sample}/A_{standard})$$

All analyses performed at the pilot plant site utilized the equipment purchased for this project. Settings used for the gas chromatograph and concentrator are presented in Attachment 1.

Attachment D-1

GAS CHROMATOGRAPH AND CONCENTRATOR SETTINGS USED FOR ANALYSES

Monitor controls		1	250
		2	0
		3	200
		4	0
Oven Program		Initial Temperature	40°C
		Final Temperature	170°C
		Program Rate	8°/min.
		Initial Hold	4 min.
		Final Hold	6 min.
Detector		Solvent Flow	3.7
		Reactor Temperature	824°C
Gas Flows	(1)	He - cold (R.T.)	3.0
		- hot (170)	2.4
	(3)	H_2	20
Gas Regulators		He	62 lb/in^2 (427.49 kPa)
		H_2	44
Tekmar		He Flow	18
		Purge Time	11 min.
		Desorb. Temp.	200°C
		Trap Bake Temp.	250°C

Attachment D-2

QUALITY ASSURANCE, QUALITY CONTROL (QA/QC) FOR GLEN COVE

The purpose of a QA/QC program is to make sure that the results being reported are within the accepted range of variability from the actual value. For this purpose, a number of steps are taken:

1. The purest chemicals available are used for standards.
2. From these, high concentration standards (2-20 g/L) for each pollutant in question are made. Fresh high concentration standards are constituted every other month.
3. Low concentration standard (1-200 mg/L) containing all the pollutants in question in ratios similar to those found in samples to be analyzed are formulated every two weeks.
4. All standard solutions use the highest quality methanol as solvent. Similarly, distilled water which has been passed through activated carbon and then purged with helium and kept under a helium atmosphere is used to make the final dilution of standards for analysis.
5. All standards to be used are analyzed at least in duplicate. Agreement of peak areas must be within 10% for duplicates. The values should not vary greatly from day to day.
6. The area of a sample pollutant must be within a factor of two of a standard (-50%, +100%). If a sample peak area falls between two standard concentrations whose areas are known, the pollutant's area is calculated by interpolation.

Attachment D-3

SAMPLING PROCEDURE

All samples should be collected in duplicate.

LIQUIDS

Vials: Screw cap glass vials with teflon-faced silicone septum. Size 25 ml.

1) Slowly fill the vial to overflowing.
2) Carefully set the container on a level surface. There should be a convex meniscus rising above the lip of the vial.
3) Place the septum, teflon side down, on the convex sample meniscus.
4) Seal the sample with the screw cap.
5) Invert the vial and lightly tap the lid on a solid surface. The absence of entrapped air bubbles indicates a proper seal.
6) If bubbles are present, open the bottle, add more sample, and reseal. Return to step 5.
7) When no bubbles are present, label the sample vial using a waterproof label* and water proof ink.
8) If samples are not to be analyzed immediately, they should be refrigerated.

* The label should show: sample number, date of sampling, sampling point, preservative added (if any), sampler.

APPENDIX E

REFERENCES

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REFERENCES

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